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ABSTRACT

Information sheets and student worksheets for twenty-eight lesson plans designed for a second-year electrical apprentice technical training program are presented in this workbook. The information sheets provide summary information about the lesson topics and the worksheets contain problems to be solved and questions to be answered relating to each lesson. Some of the lesson topics are electrical systems, single phase transformers, grounded conductors, outside branch circuits, three phase motors, lighting fixtures, sample house plans, and outlet circuiting. (The instructor's manual containing lesson plans, unit tests, and worksheet answers is available as CE 018 355. Other related documents are CE 018 350-360.) (JH)

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ED 160 881

STUDENT WORKSHEETS

RELATED INSTRUCTIONAL MATERIAL

FOR

ELECTRICAL APPRENTICE

TECHNICAL TRAINING

SERIES NO. B

(SECOND YEAR)

Revised to meet 1978 Electrical Code

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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PROGRAM DEVELOPMENT
DEPARTMENT OF COMMUNITY COLLEGES
RALEIGH, NORTH CAROLINA

CE 018 336

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FOREWORD

The apprenticeship programs offered in North Carolina are important phases of the total educational program for industry in the state. The program of education for modern apprenticeship includes two distinct phases. The first phase is "on-the-job training." The student is employed by a firm in which duties are specifically assigned to enhance ones learning in the field of study. These experiences are planned and supervised so that the individuals will progress through the apprenticeship phase to that of the journeyman. The second phase of the program of education is termed "related instruction." In this phase the apprentice is provided the technical and theoretical foundation subjects that help one to learn the trade thoroughly and accurately. This portion is usually taught through evening school, but in some cases may be done through correspondence courses.

The North Carolina Department of Community Colleges, through the Program Development Section, has the responsibility for developing and making available the instructional materials that provide the learner with a sound educational program which is effective and appropriate to the method in which the materials are being utilized. The department has available these materials for the students, as well as support material for the instructor who teaches or who acts as counselor in conducting the related classes.

Roger G. Worthington

Roger G. Worthington, Director
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Ben E. Fountain, Jr.

Ben E. Fountain, Jr., State President
Department of Community Colleges

PREFACE

The Program Development Section of the Department of Community Colleges has the responsibility for making available the related instructional materials required for use in occupational programs offered by the various institutions. This responsibility is accomplished by working with advisory committees and consultants representing each of the occupations in determining the needs and in developing the materials required to meet these needs.

These information sheets and worksheets have been prepared to provide specific assignments for studying related topics necessary in the training of electrical apprentices. An effort was made to develop the schedule to follow as the apprentice progresses with training. It will also enable the apprentice to know what skills and knowledges will be required. The objective of this program is to aid the instructor and employer in providing experiences necessary to develop not only a competent worker in the electrical field, but also, a well-rounded citizen.

This workbook includes assignment sheets and information sheets for the electrical apprentice to use in searching out related information. The worksheets contain problems to solve, questions to answer diagrams to draw, and blueprints to consult. The apprentice should study the references (assigned by the instructor) before attempting to answer the questions or solve the problems.

In actual use of these lessons, instructors should feel free to modify their application of the material to conform with local needs. For example, there may be certain sections of the Code to teach because the apprentices are working with special installations. Thus, the instructor should lead a discussion on materials that applies to these situations. In other classes, the instructor may need to spend more time with the students on topics dealing with mathematics than with blueprint reading. In any event, the minimum class time for related material is 144 hours per year. It is sincerely hoped that the assignment sheets are used correctly so that apprentices can gain maximum benefits from their related studies.

ELECTRICAL APPRENTICESHIP TECHNICAL TRAINING

ACKNOWLEDGMENTS

Questions and problems for the Lesson Topics were prepared in July, 1964 by:

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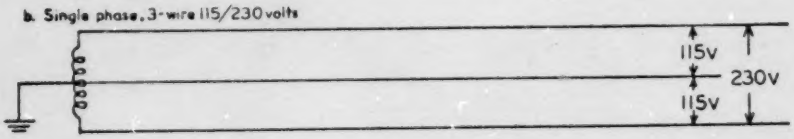
ELECTRICAL SYSTEMS

The following four pages of Information Sheets contain the several voltage classifications, nomenclature, and preferred ratings.

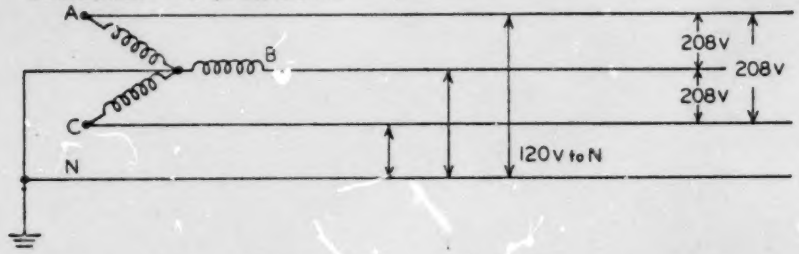
TYPES OF A.C. DISTRIBUTION 600 VOLTS OR LESS

a. Single phase, 2-wire, 115 volts

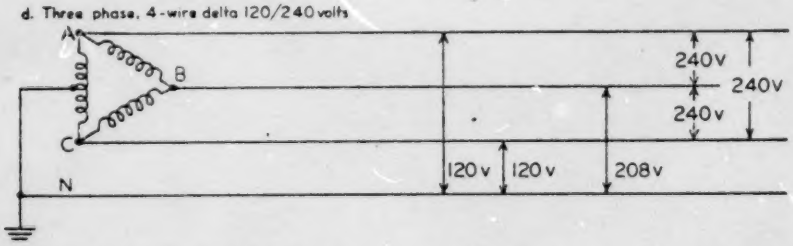
b. Single phase, 3-wire 115/230 volts



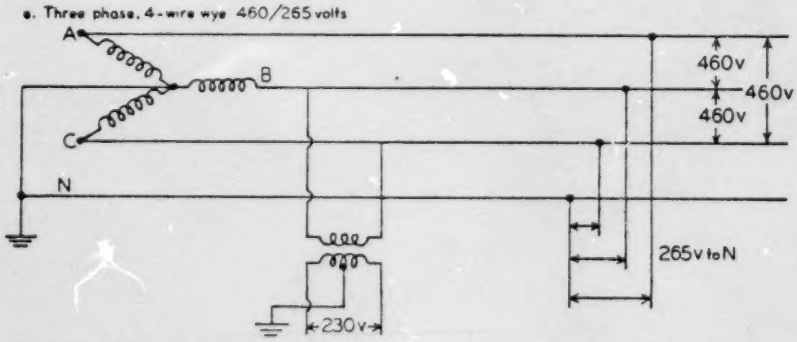
c. Three phase, 4-wire wye 120/208 volts



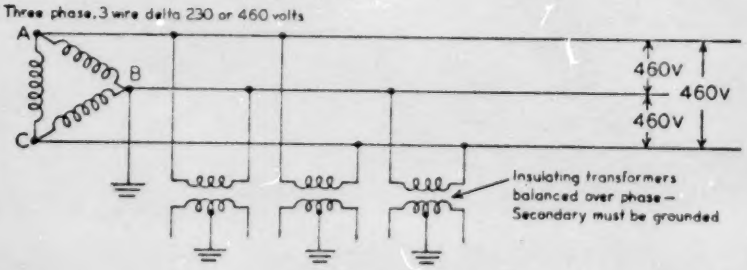
d. Three phase, 4-wire delta 120/240 volts



e. Three phase, 4-wire wye 460/265 volts



f. Three phase, 3 wire delta 230 or 460 volts



Preferred System Voltage Nomenclature, Three-Phase Systems

Industrial and Commercial Power Systems									Electrical Utility Power Systems	
Preferred Nominal System Voltage		Voltage Zones							Preferred Nominal System Voltage	
4-wire Wye	3-wire Wye or Delta	Favorable Zone			Tolerable Zone				4-wire Wye	3-wire Wye or Delta
		Minimum		Maximum	Minimum		Maximum			

VOLTAGES AT POINT OF UTILIZATION EQUIPMENT

Low-Voltage Systems

208Y/120		197Y/114	(94.7%)	216Y/125	(103.8%)	183Y/111	(92.4%)	220Y/127	(105.8%)	120/208Y
	230	210	(91.3%)	240	(104.3%)	200	(87.0%)	250	(108.7%)	230
	460	420	(91.3%)	480	(104.3%)	400	(87.0%)	500	(108.7%)	460
460Y/265(b)		434Y/250	(94.3%)	480Y/277	(104.3%)	422Y/244	(91.7%)	500Y/288	(108.7%)	265/460Y(b)
	575	525	(91.3%)	600	(104.3%)	500	(87.0%)	625	(108.7%)	575

Medium-Voltage Systems

	2400	2200	(91.7%)	2450	(102.1%)	2100	(87.5%)	2540	(105.8%)	2400
	4160	3810	(91.7%)	4240	(102.1%)	3630	(87.5%)	4400	(105.8%)	4160
	480C	4400	(91.7%)	4900	(102.1%)	4200	(87.5%)	5080	(105.8%)	4800
	690C	6320	(91.7%)	7050	(102.1%)	6040	(87.5%)	7300	(105.8%)	6900
	13,800	12,630	(91.7%)	14,100	(102.1%)	12,080	(87.5%)	14,600	(105.8%)	

PRIMARY VOLTAGES AT DISTRIBUTION TRANSFORMERS

Medium-Voltage Systems

		2300	(95.8%)	2500	(104.2%)	2200	(91.7%)	2540	(105.8%)	2400
		2300/4000Y	(95.8%)	2500/4330Y	(104.2%)	2200/3810Y	(91.7%)	2540/4400Y	(105.8%)	2400/4160Y
		4600	(95.8%)	5000	(104.2%)	4400	(91.7%)	5200	(108.3%)	4800
		6900	(95.8%)	7500	(104.2%)	6600	(91.7%)	7800	(108.3%)	7200
		4600/8000Y	(95.8%)	5000/8660Y	(104.2%)	4400/7620Y	(91.7%)	5200/9000Y	(108.3%)	4800/8320Y
		11,000	(91.6%)	12,500	(104.2%)	10,500	(87.4%)	13,000	(108.3%)	12,000
		6900/12,000Y	(95.8%)	7500/13,000Y	(104.2%)	6600/11,450Y	(91.7%)	7800/13,500Y	(108.3%)	7200/12,470Y
		12,600	(95.4%)	13,800	(104.5%)	12,100	(91.7%)	14,300	(108.3%)	13,200
		7270/12,600Y	(95.4%)	7960/13,800Y	(104.5%)	7000/12,100Y	(91.7%)	8250/14,300Y	(108.3%)	7620/13,200Y
		13,000	(90.3%)	14,500	(100.7%)	12,600	(87.4%)	15,000	(104.2%)	14,400

VOLTAGES AT SUBSTATIONS OR ON SUBTRANSMISSION OR TRANSMISSION SYSTEMS

Medium-Voltage Systems

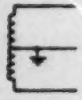
	2400	2300	(95.8%)	2600	(108.3%)	2200	(91.7%)	2750	(114.6%)	2400
	4160	4000	(95.8%)	4500	(108.3%)	3810	(91.7%)	4760	(114.6%)	
		2300/4000Y	(95.8%)	2600/4500Y	(108.3%)	2200/3910Y	(91.7%)	2750/4760Y	(114.6%)	2400/4160Y
	480C	4600	(95.8%)	5200	(108.3%)	4400	(91.7%)	5500	(114.6%)	4800
	690C	6600	(95.8%)	7470	(108.3%)	6320	(91.7%)	7900	(114.6%)	
		6900	(95.8%)	7800	(108.3%)	6600	(91.7%)	8250	(114.6%)	7200
		4600/8000Y	(95.8%)	5200/9000Y	(108.3%)	4400/7620Y	(91.7%)	5500/9520Y	(114.6%)	4800/8320Y
		11,000	(91.6%)	13,000	(108.3%)	10,500	(87.4%)	13,200	(110.0%)	12,000
		6900/12,000Y	(95.8%)	7800/13,500Y	(108.3%)	6600/11,450Y	(91.7%)	7920/13,700Y	(110.0%)	7200/12,470Y
		12,600	(95.4%)	14,300	(108.3%)	12,100	(91.7%)	14,500	(110.0%)	13,200
		7270/12,600Y	(95.4%)	8250/14,300Y	(108.3%)	7000/12,100Y	(91.7%)	8320/14,500Y	(110.0%)	7620/13,200Y
	13,800	13,200	(95.8%)	14,950	(108.3%)	12,630	(91.7%)	15,000	(108.4%)	
		13,000	(90.3%)	15,000	(104.2%)	12,600	(87.4%)	15,500	(107.7%)	14,400

High-Voltage Systems

	23,000	See	See	20,400	(88.7%)	25,800	(112.3%)	23,000
	27,600	Note 1	Note 1	24,500	(88.7%)	31,000	(112.3%)	27,600
	34,500			30,600	(88.7%)	38,000	(110.0%)	34,500
	46,000			40,000	(86.9%)	48,300	(105.0%)	46,000
	69,000			60,000	(86.9%)	72,500	(105.1%)	69,000
	115,000			100,000	(86.9%)	121,000	(105.1%)	115,000
	138,000			120,000	(86.7%)	145,000	(105.0%)	138,000
	161,000			140,000	(86.9%)	169,000	(105.0%)	161,000
	230,000			200,000	(86.9%)	242,000	(105.2%)	230,000

Note 1: For systems with nominal voltages above 13,800 volts, the designation of a "favorable zone" has been omitted as being somewhat less necessary than for the lower voltages.

Preferred System Voltage Nomenclature, Single-Phase Systems

Industrial and Commercial Power Systems									Electrical Utility Power Systems	
Preferred Nominal System Voltage		Voltage Zones							Preferred Nominal System Voltage	
 3-wire	2-wire	Favorable Zone			Tolerable Zone				3-wire	2-wire
		Minimum		Maximum	Minimum		Maximum			
VOLTAGES AT POINT OF UTILIZATION EQUIPMENT Low-Voltage Systems										
120/240	120	110	(91.7%)	125	(104.2%)	107	(89.2%)	127	(105.8%)	120/240	120
		110/220	(91.7%)	125/250	(104.2%)	107/214	(89.2%)	127/254	(105.8%)	240/480	
		220/440	(91.7%)	250/500	(104.2%)	214/428	(89.2%)	254/508	(105.8%)		

Preferred Voltage Ratings for Alternating-Current Equipment

Preferred Nominal System Voltage	Generator Rated Voltage	Transformer Secondary Rated Voltage	Transformer Primary Rated Voltage	Switchgear Nominal Rated Voltage	Capacitor Rated Voltage	Motor and Control Rated Voltage	Ballast Rated Voltage
Single-Phase Systems and Single-Phase Components Applied on Three-Phase Systems							
120	120	120	120	120		115	120
120/240	120/240	120/240	240	240	230 or 240	230	236 or 240
208Y/120, 3-phase	125/216Y, 3-phase	216Y/125, 3-phase	120	240	230 or 240	115*	120*
460Y/265, 3-phase	277/480Y, 3-phase	480Y/277, 3-phase	480	480	460 or 480		265* or 277*
Three-Phase Low-Voltage Systems							
208Y/120	125/216Y	216Y/125	208	240	216 or 230 or 240	208 or 220	208†
230	139/240Y	240Y/139 or 240	240	240	230 or 240	220	236† or 240†
460Y/265	277/480Y	480Y/277	480	480	460 or 480	440	460† or 480†
460	277/480Y	480Y/277	480	480	460 or 480	440	460† or 480†
575	346/600Y	600Y/346 or 600	600	600	575 or 600	550	
Three-Phase Medium-Voltage Systems							
2,400	1,388/2,400Y	2,400Y/1,388 or 2,400	2,400	2,400	2,400	2,300	
4,160	2,400/4,160Y	4,160Y/2,400	4,160	4,160	2,400 or 4,160	4,000	
4,800	2,770/4,800Y	4,800Y/2,770 or 4,800	4,800	13,800 or 7,200	2,770 or 4,800	4,600	
6,900	3,980/6,900Y	6,900Y/3,980	6,900	7,200	4,160 or 6,640	6,600	
7,200	3,980/6,900Y	7,200Y/4,160	7,200	13,800 or 7,200	4,160 or 7,200	6,600	
12,000	7,210/12,500Y	12,000Y/6,920	12,000	13,800	7,200 or 12,470	11,000	
7,200/12,470Y	7,210/12,500Y	12,470Y/7,200	12,000	13,800	7,200 or 12,470		
13,200	7,970/13,800Y	13,200Y/7,610	13,200	13,800	7,620 or 13,800	13,200	
13,800	7,970/13,800Y	13,800Y/7,970	13,800	13,800	7,960 or 13,800	13,200	
14,400	8,320/14,400Y	13,800Y/7,970	13,800	14,400	7,960 or 13,800 or 14,400	13,200	

* Line-to-neutral rating.

† Line-to-line rating.

NAME _____ LESSON B-1

DATE _____ WORKSHEET

ELECTRICAL SYSTEMS

1. From the Information Sheet which shows the types of A.C. distribution 600 volts or less, list one type of customer for each installation.

   (a) Single phase, 2 wire, 115 volts _____
   (b) Single phase, 3 wire, 115/230 volts _____
   (c) Three phase, 4 wire, 120/208 volts _____
   (d) Three phase, 4 wire delta, 120/240 volts _____
   (e) Three phase, 4 wire wye, 460/265 volts _____
   (f) Three phase, 3 wire delta, 230 or 460 volts _____

2. Which of the above types of distribution systems is referred to as "High Leg"? _____

3. Which phase (or leg) would be labeled as the "High Leg"? _____ What is its N. E. Code color coding? _____ List the N.E.C. reference. _____

4. What color coding is applied to the "Intentionally grounded" conductor of the transformer? _____ What is the common term for this conductor? _____

5. What other three phase, "3 wire delta voltage" is used for large manufacturing plants? _____

6. List two ways to obtain 120 volt power in an installation using a three phase, "3 wire delta" service. (a) _____ or (b) _____

7. The two standard frequencies used in this country are _____ and _____ cycles.

8. Which frequency is the most widely used? _____

9. There are no standard voltages for D. C. equipment. The most common D. C. voltage is _____. Some manufacturers list 125, 250, 600 and 750 volt equipment.

10. List four reasons for providing separate circuits for lighting loads and motor loads.

(a) _____

_____

(b) _____

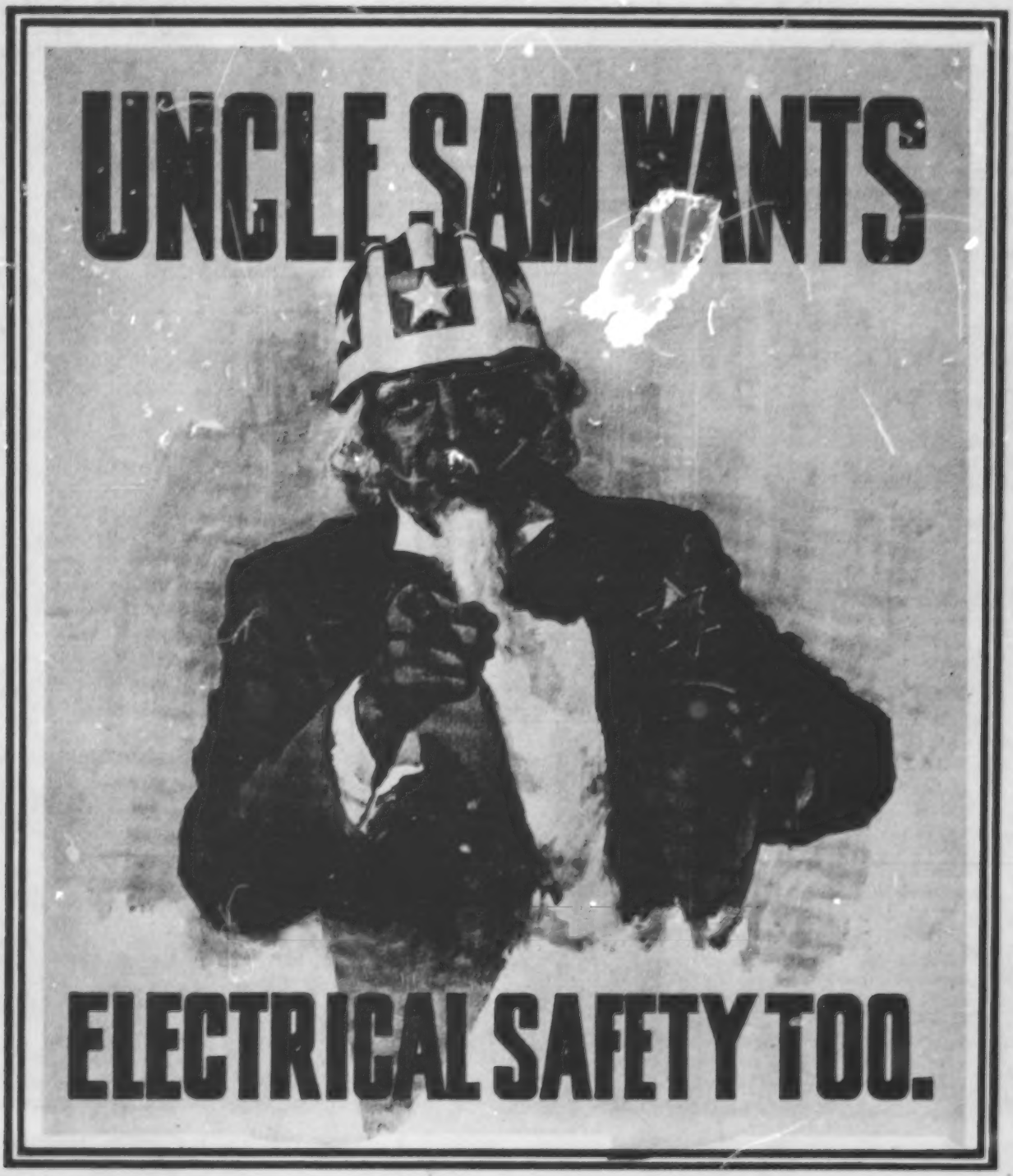
_____

(c) _____

_____

(d) _____

_____


UNCLE SAM WANTS
ELECTRICAL SAFETY TOO.

A. C. INSTRUMENTS AND THEIR USE

GENERAL INFORMATION:

1. When using an Ohmmeter, be sure that the circuit is dead.
2. When using a Multi-meter, be sure the Selector Switch is set for what you want to check.
3. Never exceed the Unit of Meter scale. Always start at the highest multiplier and work down.
4. Never connect a Voltmeter in series with a load. It has a high Internal Resistance and will burn up if connected in series.
5. Never connect an Ammeter parallel. It has a low internal resistance.

NAME _____ LESSON B-2

DATE _____ WORKSHEET

A. C. INSTRUMENTS AND THEIR USE

1. MATCH: Place the number representing the name of the instrument in Column B on the line giving the use, Column A.

Column A	Column B
_____ a. An instrument used to measure VOLTAGE.	1. Ohmmeter
_____ b. An instrument used to measure POWER.	2. Ammeter
_____ c. An instrument used to measure CURRENT.	3. Voltmeter
_____ d. An instrument used to measure RESISTANCE.	4. Megameter
	5. Wattmeter

2. When using a Voltmeter to test a circuit, how should it be connected?

_____

3. Draw a schematic of a circuit showing a LIGHT, POWER SUPPLY, and a SWITCH. Show the Voltmeter connection to measure the "Drop" across the LIGHT. ____

4. (a) How should an AMMETER be connected in the circuit to be tested?

_____

(b) Draw a schematic of a circuit using the same equipment in Question Number 3 and show how the AMMETER should be connected.

5. Give one main purpose of a "megger" or megameter.

_____

6. (a) What is a MULTI-RANGE AMMETER? _____

_____

(b) What is a MULTI-RANGE VOLTMETER? _____

_____

7. Mark T for TRUE and F for FALSE on the line in front of the statement. Give reference proof for your answer on line at the end of each statement.

_____ a. When using the ohmmeter, the cirucit should be dead.
Reason or Ref. _____

_____ b. Connect an ammeter parallel in the circuit.
Reason or Ref. _____

_____ c. Use a voltmeter to measure the resistance of a circuit.
Reason or Ref _____

_____ d. When the resistance of a load is given and you have a voltmeter to measure the "Voltage Drop," the current can be found without using an ammeter.
Reason or Ref. _____

8. What is a multi-meter? _____

_____

9. Explain the "Bell" or "Buzzer" method for location and identifying conductors. _____

_____

10. List 5 pieces of Test Equipment in general use.

(a) _____ (b) _____

(c) _____ (d) _____

(e) _____

PRINCIPLES AND TYPES OF TRANSFORMERS

The basic theory of transformers will be found in your reference texts along with appropriate illustrations and schematic drawings. These lessons should help you to understand more about the principles of operation, the construction and the installation of the transformers in common use. Be sure to study thoroughly the assigned references found in the American Electrician's Handbook, and also, the other references.

This lesson should help you to understand the electrical principles as they apply to transformers. This knowledge will in turn help you to become a valuable mechanic on the job when there are transformers to be installed.

You will study how the voltage of a source of supply (primary coil) can be used to induce a current into another coil (secondary). This is accomplished by means of mechanical movement through the electromagnetic field or the use of alternating current. Thus the transformer is an inductive device used in alternating current distribution and changes the voltage to higher or lower amounts where needed. As you have learned, a current that flows in one direction and then in another (reversing) is called an alternating current. A transformer ordinarily has an alternating current flow through its primary coil and always has an alternating current induced in its secondary coil. It is doubtful if there would be an electrical industry, if the transformer principle had not been discovered and developed.

The lesson concerns itself with some of the many types of transformers. Transformers are designed for many different uses and frequencies. The type of transformer you will be most concerned with is the power supply transformer. While there are many types you probably will never see on the job, the types studied here are very common and should be familiar to every electrician.

NAME _____ LESSON B-3

DATE _____ WORKSHEET

PRINCIPLES AND TYPES OF TRANSFORMERS

1. A _____ is a device for changing _____ energy from one potential to another.

2. What are the two windings of a transformer called?

   a. _____ b. _____

3. In transformers the primary winding is connected to the LOAD side and the secondary winding is connected to the LINE side. True/False _____

4. A step-up transformer delivers energy at a:

   a. Lower Potential
   b. Higher Potential
   c. Upstairs
   d. Same Potential

5. List three types of losses in a transformer:

   a. _____ b. _____ c. _____

6. What type of transformer delivers voltage at a lower potential than it receives? _____

7. Basic construction of a transformer consist of the following:

   a. _____ b. _____

   c. _____

8. Transformers are rated in: _____

   a. KVA b. TVA c. KWH d. Amps

9. Describe the principle operation of a transformer.

   _____

10. The regulation of a transformer is the amount the voltage varies with changing load. True/False _____

11. In general the power input of a transformer equals the power output. True/False _____

12. What is the correct formula for transformer efficiency ratio?

a. $\frac{\text{output}}{\text{output + copper \& iron losses}}$

b. $\frac{\text{output}}{\text{input + copper \& iron losses}}$

c. $\frac{\text{input}}{\text{output}}$

d. $\frac{\text{output}}{\text{output - copper \& iron losses}}$

13. List six main classifications of transformers:

a. _____ d. _____

b. _____ e. _____

c. _____ f. _____

14. A varying potential transformer is designed to vary the secondary voltage with load on a constant potential supply.
True/False _____

15. Which of the following formula is correct for transformer ratio between voltage, current and turns? _____

a. $\frac{Ep}{Es} = \frac{Ip}{Is} = \frac{Tp}{Ts}$

b. $\frac{Es}{Ep} = \frac{Tp}{Ts} = \frac{Ip}{Is}$

c. $\frac{Ep}{Es} = \frac{Tp}{Ts} = \frac{Is}{Ip}$

16. The power formula for single phase is:

a. $P = EI$ b. $P = \frac{E}{I}$ c. $P = \frac{I}{E}$ d. $P = E + I$

17. Find the ratio of a transformer having a 600 volt primary and a 120 volt secondary.

18. Find secondary amps of a transformer having 5 amps primary, primary volts 600, and secondary volts 120.

$\frac{Ep}{Es} = \frac{Is}{Ip}$

19. Find the primary amps of a transformer having secondary amps 40, primary volts 440, secondary volts 220.

$\frac{Ep}{Es} = \frac{Is}{Ip}$

20. Find the primary volts of a transformer having secondary volts 120, primary amps 5, and secondary amps 25.

$$\frac{Ep}{Es} = \frac{Is}{Ip}$$

21. Find the secondary volts of a transformer having primary volts 13,800, primary amps 4, and secondary amps 92.

$$\frac{Ep}{Es} = \frac{Is}{Ip}$$

22. Find the primary turns of a transformer having 100 turns secondary, 440 volts primary, 220 volts secondary, and 2 amps primary.

$$\frac{Ep}{Es} = \frac{Tp}{Ts} = \frac{Is}{Ip}$$

23. Find the primary and secondary watts that a transformer draws from the line with primary turns 100, secondary turns 20, primary volts 120, and secondary amps 5. Assume 100% efficiency:

$$\frac{Ep}{Es} = \frac{Tp}{Ts} = \frac{Is}{Ip}$$

$$P = EI$$

24. Find the efficiency of a transformer with 200 watts primary and 190 watts secondary.

$$\frac{\text{Output}}{\text{Input}} =$$

25. The input of a transformer is the same as the output plus copper and iron losses. True/False _____

26. Find the percent regulation of a transformer which reads 575 volts secondary at no load and 550 volts secondary at full load.

$$\text{Percent Reg.} = \frac{\text{No load sec. - full load sec.}}{\text{Full load sec.}}$$

TRANSFORMER DEFINITIONS AND TERMS

A. Air-cooled--A transformer which uses air as the cooling medium. This may be natural draft cooling by convection, or forced air with the use of fans.

Ambient Noise Level--The existing or inherent sound level of the area surrounding a transformer installation measured in decibels.

Ambient Temperature--The inherent or existing temperature of the atmosphere surrounding the transformer installation into which the heat losses of the transformer are dissipated.

ANSI--American National Standards Institute is the recognized body which specifies the standards on transformers. ANSI C 89.1 and C 57.12 are the standards most often used.

Askarel-- Non-flammable liquid with high dielectric strength. Primarily used for cooling and insulating liquid filled transformers installed indoors.

Auto-Transformer--A transformer which has only one winding per phase, part of which is common to both primary and secondary circuits.

B. BIL--Basic Insulation Level is a reference insulation level expressed as the maximum crest voltage that the insulation will withstand when a 1.5 x 40 microsecond pulse is applied. This is a measure of the ability of the insulation to withstand very high voltage surges.

Buck Boost--An insulating transformer which has low voltage secondary windings (usually 12/24 or 16/32 V.) and is normally connected as an auto-transformer for raising or lowering the supply voltage in small amounts.

C. Center Tap--A reduced capacity tap at the mid point in a winding.

Certified Test--Actual production or laboratory tests which certify values as having been taken on a specific item, on a specific order.

Compensated Transformer--A transformer with a turns ratio which provides a higher than rated voltage at no load and rated voltage at rated load.

Continuous Rating--Refers to the load that a transformer can handle indefinitely without exceeding the specified temperature rise.

Control Transformer--A transformer which is designed for good voltage regulation characteristics when low power factor, large in-rush currents are drawn (5 to 15 times normal).

Conductor Losses--Losses caused by the resistance of the transformer winding and usually measured at 25, 50, 75, and 100 percent of load.

Core Loss--Losses caused by a magnetization of the core and its resistance to magnetic flux.

Current Transformer--A transformer designed to have its primary winding connected in series with the circuit and used for transforming current to a value suitable for measurement or control.

D. Decibel--(DB) The standard unit used in the measurement of sound intensity. See discussion on sound levels in the Application and Engineering Data section.

Delta--(Δ) A standard three phase connection in which each phase winding is connected in series to form a closed loop.

Delta Wye--(Δ-Y) The term used when indicating the method of connection for both the primary and secondary windings of a three phase transformer bank.

Dielectric Tests--A series of tests conducted at much higher than rated nameplate voltage to determine the effectiveness of insulating materials and electrical clearances.

Distribution Transformer--Any transformer rated between 3 and 500 KVA, inclusive, with a primary voltage of 601 volts or greater.

Dry Type Transformer--A dry type transformer is one which does not employ a liquid as a cooling or insulating medium.

Dual Winding--A winding that consists of two separate windings which can be connected in series to handle a specified voltage and KVA, or in parallel to handle the same KVA at one-half the series connected voltage.

E. Electrostatic Shield--A grounded conductor sheet placed between the primary and secondary windings to prevent the transfer of radiated electrical energy or interference from one circuit to the other.

Exciting Current--The current which maintains the excitation of a transformer--the current that flows in the primary when the load is disconnected. Usually expressed in percent of the rated current of the winding.

Extended Winding--A winding with additional turns to provide application of a higher voltage. This effectively changes the turns ratio of the transformer when the extended winding is employed in the circuit. Example: FCAN taps.

F. FCAN--Full capacity above normal taps. The designation used to indicate that a transformer will deliver rated KVA when connected to a voltage source which is higher than rated voltage.

FCBN--Full capacity below normal taps. Same as FCAN except that the taps are below rated voltage.

Fan Cooled--A means of accelerating heat dissipation to lower the temperature rise of the transformer. This has the effect of increasing the transformer rating.

Filter Press--A device for absorbing moisture from oil or askarel. Liquid is force-circulated through absorbent pads.

Flexible Connector--A pliable conductor, conduit or wire-way designed to compensate for thermal expansion and contraction, or reduce the transmission of objectionable noise.

Frequency--The number of times an AC voltage will alternate from positive to negative and back again within a specified period of time, usually expressed in cycles per second and identified as Hz as in 60 Hz.

Full Capacity Tap--Tap that is designed to deliver the rated capacity of the transformer.

G. Grounding Transformer--A special three phase auto-transformer used to establish a stable neutral point on a three wire delta system (See Zig-Zag Transformer).

H. Hertz (Hz)--Expression of AC frequency in cycles per second. (Example--60 Hz)

High Reactance Transformer--A design which has high leakage reactance to limit output current to a designated value in the event of a fault. Also called Energy Limiting transformer.

Hi Pot--A standard dielectric test to check insulating materials and clearances between windings and between winding and ground.

I. Impulse Tests--The test employed to determine basic Insulation level (BIL).

Impedance--The vector sum of resistance and reactance which limits the current flow in an AC circuit.

Induced Potential Test--A standard dielectric test which verifies the ability of insulating materials and electrical clearances between turns and between layers of a transformer winding.

Inrush Current--An abnormally high current which is occasionally drawn when a transformer is first energized, due to residual flux in the core.

Instrument Transformer--A transformer designed to transform the conditions of current or voltage and phase position in the primary, with a specified accuracy in the secondary circuit.

Insulating Material--Organic or inorganic substances which prevent or greatly reduce the current flow between live parts or between live parts and ground.

Insulating Transformer--One in which the primary winding is insulated from the secondary winding.

Interleaving--A method of winding where the primary and secondary are wound in sections, with a section of the primary between two sections of the secondary and vice versa. This technique is used to reduce the leakage reactance of the transformer when desirable to do so.

Isolating Transformer--A transformer which insulates the primary circuit from secondary circuit as with an insulating transformer, but frequently with no voltage change.

J. Jack Pads--Structural member at bottom of transformer tank to accomodate Hydraulic Jacks which lift unit onto rollers for moving into position.

K. KVA--Kilovolt Ampere rating designates the output which a transformer can deliver at rated voltage and frequency without exceeding a specified temperature rise.

L. Liquid Filled Transformer--One in which the core and coil structure is immersed in a liquid, usually oil, which acts as both a cooling and insulating medium.

Liquid Level Gauge--Indicates level of liquid within tank. Normal level indicated at 25°C. Operates by magnetic coupling.

Load--The KVA or VA requirement which the transformer must supply.

Load Center Unit Substation Transformer--A transformer that is mechanically and electrically connected to and coordinated in design with switchgear or motor control assemblies.

Load Losses--Those losses which are the result of a current flowing to the load. Load losses would include all losses incurred above and beyond the no-load losses.

M. Multiple Winding--A winding which consists of two or more sections that can be paralleled for a specific mode of operation.

N. NEMA Standard--Any standard recommended by the National Electrical Manufacturers Association.

Network Transformer--A transformer which is electrically and mechanically connected to and coordinated in design with switchgear or motor control assemblies for use on a utility network power system.

No-Load Losses--The losses incurred when a transformer is excited but without a load connected to the secondary. These include core loss, dielectric loss, and exciting current I^2R loss.

P. Parallel Operation--Transformers or transformer windings may be connected in parallel provided that the electrical characteristics are suitable for such operation.

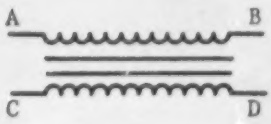
Percent IR--(% IR)--Percent Resistance--The voltage drop due to conductor resistance at rated current expressed in percent of rated voltage.

Percent IX--(% IX)--Percent Reactance--The voltage drop due to reactance at rated current expressed in percent of rated voltage.

Percent IZ--(% IZ)--Percent Impedance--The voltage drop due to impedance at rated current expressed in percent of rated voltage.

Phase--Classification of an AC circuit, usually single phase, two wire or three wire; two phase, three wire or four wire; or three phase, three wire or four wire.

Polarity--A designation of the relative instantaneous direction of the current in a secondary lead as compared with a primary lead. The two leads are said to be of the same polarity when, at any instant, the currents in the two leads are flowing in the same direction as if the leads were a single piece of wire. The polarity of a single phase transformer is classed as either additive or subtractive:



With leads A and C connected together and a voltage applied between A and B, the polarity is said to be additive if the voltage between B and D is greater than the applied voltage. If the voltage between B and D is less than that applied, the polarity is said to be subtractive.

Polyphase--More than one phase.

Potential Transformer--A transformer that is designed to have its primary winding connected parallel with a circuit and used for transforming voltage to a value suitable for measurement or control.

Power Factor--The ratio of watts to volt amperes in a circuit. Expressed as watts/VA.

Power Transformer--Any transformer rated above 500 KVA at a voltage of 601 volts or above.

Pressure Relief Device--Used to relieve excessive pressure inside tank. Generally operates at 7 1/2 psi. Self-resealing with target indicator to show operation. Alarm contacts are optional.

Pressure Vacuum Bleeder Valve--Automatic valve which opens and closes to maintain internal pressure within predetermined limits.

Pressure Vacuum Gauge--Measures pressure inside tank, both above and below atmospheric.

Primary Winding--A winding connected to the voltage source or input.

R. Radiators--Tank extensions used to assist cooling the oil and transformer. Panel type is generally used for better efficiency and appearance.

Rating--This refers to the characteristics such as volt ampere capacity, voltages, frequency, and temperature rise for which a transformer is designed.

Ratio--A reference to either the turns ratio or to the voltage ratio of the transformer.

Reactance--A component of impedance produced by either inductance or capacitance in an AC circuit.

Reactor--A device generally a single winding on an air core or an iron core which produces a specific amount of inductive reactance for which it is designed.

Rectifier Transformer--A transformer designed to supply the AC input to a rectifier to the value necessary to obtain the desired DC output and have the ability to withstand the unusual heating effects caused by rectifier commutation or ripple.

Reduced Capacity Taps--Tap that is not designed to deliver the rated capacity of the transformer.

Regulation--The percent change in output voltage from full load to no load.

S. Scott Connection--A transformer connection usually used to get a two phase output from the secondary of a transformer with a three phase input to the primary, or vice versa. It can also be used to provide 3 phase to 3 phase transformation.

Secondary Winding--The transformer winding connected to the load or output side.

Sealed Dry Type Transformer--Dry type core and coils in a tank containing an inert gas such as nitrogen or freon under slight pressure.

Series/Multiple--A winding consisting of several sections which can be connected for series or parallel operation.

Star Connection--Same as the wye connection.

Step Down Transformer--One in which the high voltage winding is connected to the input or power source and the low voltage winding to the output or load.

Step Up Transformer--A transformer in which the low voltage winding is connected to the power source or input and the high voltage winding is connected to the output or load.

Sudden Pressure Relay--Pressure switch device which operates instantaneously to disconnect transformer from line. Sudden pressure is usually caused by internal transformer fault.

T. T-Connection--A Scott connected three phase transformer utilizing two primary and two secondary coils called the main and teaser coils.

Tap--A connection between transformer winding which has the effect of changing the nominal voltage ratio of the transformer.

Temperature Indicator--Measures temperature of top oil within tank. Has provision for resetting maximum temperature indication.

Temperature Rise--The temperature increase over ambient due to load. This is measured as either average rise by resistance or as hot-spot.

Thermal Overload Relay (TRO-2)--Allows loading transformer to full thermal capacity by analyzing loads, temperatures, and transformer time constant. Operates contacts for alarm and/or forced air cooling fans.

Transformer--A transformer is a static electrical device which by electro-magnetic induction transfers electrical energy from one circuit to another circuit, usually with changed values of voltage and current.

Turns Ratio--See Ratio.

V. Volt Amperes--The current flowing in a circuit multiplied by the voltage of that circuit. An expression of the output rating of a transformer.

Voltage Ratio--See Ratio.

Voltage Regulation--See Regulation.

W. Wye Connection--A three phase connection in which similar ends of each phase winding are connected together at a common point which forms the electrical neutral and is often grounded.

Z. Zig-Zag Transformer--Commonly used term for a grounding transformer.

Wiring Diagrams

Single Phase

DIAGRAM 1 NO TAPS

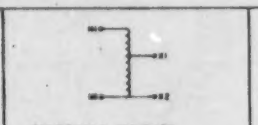


DIAGRAM 2 NO TAPS

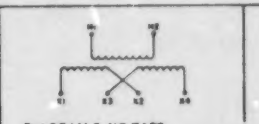


DIAGRAM 3 NO TAPS

DIAGRAM 4 NO TAPS

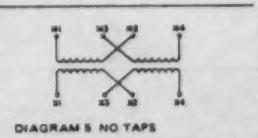


DIAGRAM 5 NO TAPS

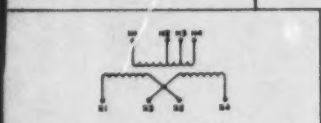


DIAGRAM 6 2.5% FCBN TAPS

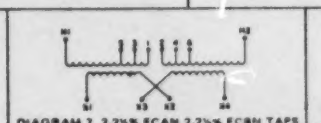


DIAGRAM 7 2.2½% FCAN 2.2½% FCBN TAPS OR 4-2½% FCBN TAPS

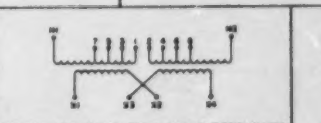


DIAGRAM 8 2.2½% FCAN 4-2½% FCBN TAPS

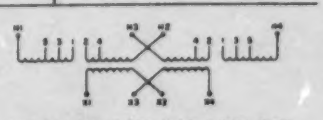


DIAGRAM 9 2.2½% FCAN 4-2½% FCBN TAPS

Three Phase "T" Connected

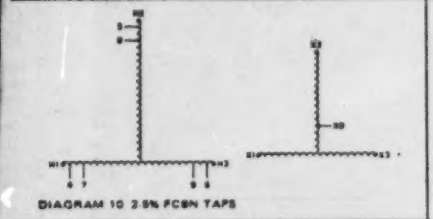


DIAGRAM 10 2.5% FCBN TAPS

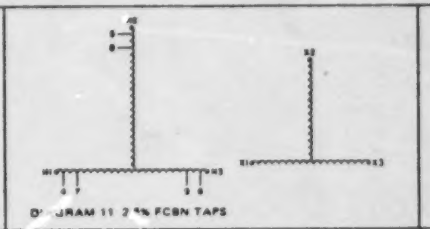


DIAGRAM 11 2.5% FCBN TAPS

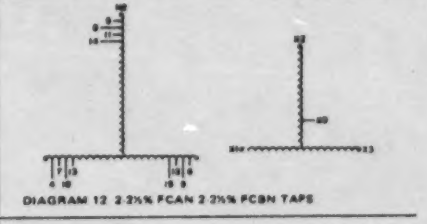


DIAGRAM 12 2.2½% FCAN 2.2½% FCBN TAPS

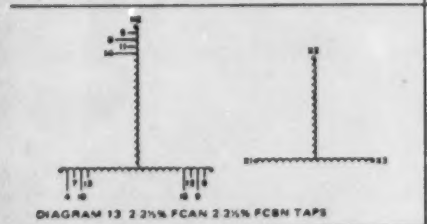


DIAGRAM 13 2.2½% FCAN 2.2½% FCBN TAPS

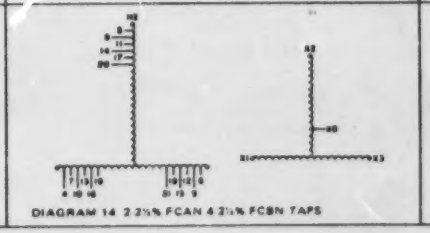


DIAGRAM 14 2.2½% FCAN 4.2½% FCBN TAPS

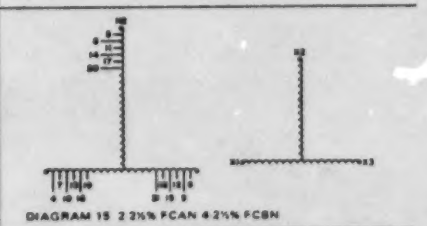


DIAGRAM 15 2.2½% FCAN 4-2½% FCBN

Three Phase

DIAGRAM 16 NO TAPS

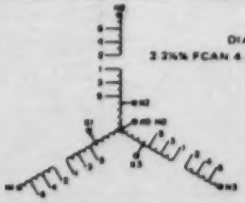


DIAGRAM 17
2-2½% FCAN 4-2½% FCBN

DIAGRAM 18 2-5% FCBN

DIAGRAM 19 2-5% FCBN TAPS

DIAGRAM 20
2-2½% FCAN 2-2½% FCBN TAPS

DIAGRAM 21
2-2½% FCAN 2-2½% FCBN TAPS

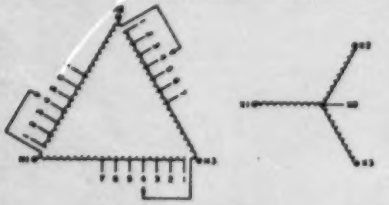


DIAGRAM 22 2-2½% FCAN 4-2½% FCBN TAPS

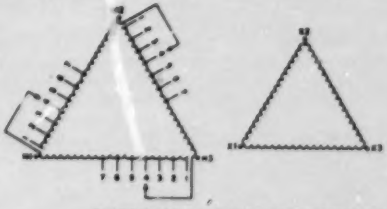


DIAGRAM 23 2-2½% FCAN 4-2½% FCBN TAPS

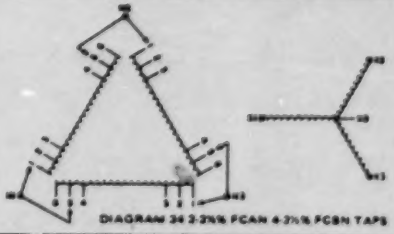


DIAGRAM 24 2-2½% FCAN 4-2½% FCBN TAPS

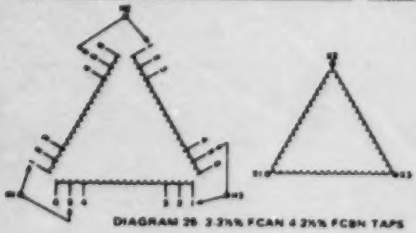


DIAGRAM 26 2-2½% FCAN 4-2½% FCBN TAPS

DIAGRAM 25 2-2½% FCAN 4-2½% FCBN TAPS

DIAGRAM 27 2-2½% FCAN 4-2½% FCBN TAPS

NAMEPLATE DESIGNATION OF VOLTAGE RATINGS OF WINDINGS

Reference NEMA Standard TR-27 & ANSI C 57.12

TABLE I – SINGLE PHASE TRANSFORMERS

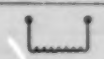
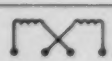
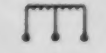
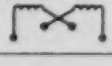
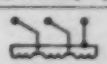
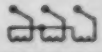
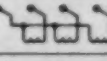
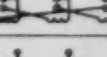
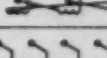
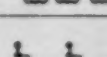
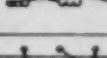
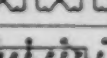
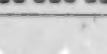
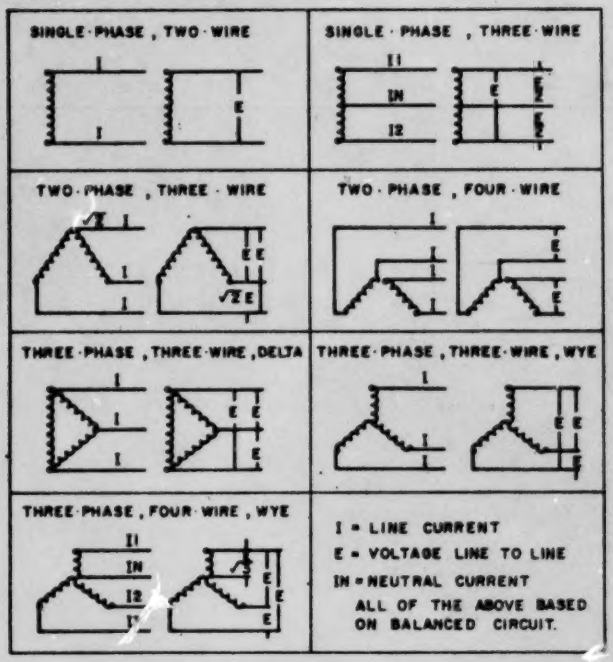
Nomenclature	Typical Examples Nameplate Marking	Typical Winding Diagram	Condensed Usage Guide
E	2400		Indicates a winding for Δ connection on an E volt system.
E/E$_1$,Y	2400/4160Y		Indicates a winding for Δ connection on an E volt system or Y connection on an E$_1$ volt system.
E/E$_1$,G=Y	38700/67000G=Y		Indicates a winding with reduced insulation for Y connection on an E$_1$ volt system with the transformer neutral effectively grounded or for Δ connection on an E volt system.
E$_1$,G=Y/E	13470G=Y/7200		Indicates a winding with reduced insulation at the neutral end. The neutral end may be connected directly to the tank for connection single phase or in Y on an E$_1$ volt system with the neutral end of the winding effectively grounded.
E/2E	120/240,240/480		Indicates a winding for multiple, series, or three-wire service.
2E/E	240/120		Indicates a winding for 2E volts, two wire full line, or for 2E/E volts three wire service with one half line available from mid-point tap (both available terminal).
V=V$_1$	240=480 or 2400/4160Y=4800/8320Y		Indicates a winding for multiple or series operation only. (Not for three-wire service.)

TABLE II – THREE PHASE TRANSFORMERS

Nomenclature	Typical Examples Nameplate Marking	Typical Winding Diagram	Condensed Usage Guide
E	240		Indicates a winding permanently Δ (Delta) connected.
EY	4160Y		Indicates a winding permanently Y connected with the neutral isolated.
E$_1$,Y/E	4160Y/2400		Indicates a winding permanently Y connected with fully insulated neutral available.
E/E$_1$,Y	2400/4160Y		Indicates a winding for connection E volts Δ or E$_1$Y volts with the neutral isolated.
E/E$_1$,Y/E	2400/4160Y/2400		Indicates a winding for connection E volts Δ or E$_1$Y volts with a fully insulated neutral available.
E$_1$,G=Y/E	67000G=Y/38700		Indicates a winding having reduced insulation and permanently Y connected with the transformer neutral grounded.
E/E$_1$,G=Y/E	38700/67000G=Y/38700		Indicates a winding having reduced insulation for Y connection on an E$_1$ volt system with the transformer neutral grounded, or for Δ connection on an E volt system.
V=V$_1$	7200=14400		Indicates a permanently Δ connected winding for multiple or series operation.
	4160Y/2400=13470Y/7200		Indicates a permanently Y connected winding for multiple or series operation.

Key: $E_1 = \sqrt{3} \times E$

SYSTEM WIRING DIAGRAMS



TRANSFORMER TAP SELECTOR CHART

Proper	Nominal Transformer Input Voltage Rating											
Tap	120	240	480	600	2400	4160	4800	7200	12470	13200	13800	14400
+5%	126	252	504	630	2520	4368	5040	7560	13094	13860	14490	15120
+2½%	123	246	492	615	2460	4264	4920	7380	12782	13530	14145	14760
Rated	120	240	480	600	2400	4160	4800	7200	12470	13200	13800	14400
−2½%	117	234	468	585	2340	4056	4680	7020	12158	12870	13455	14040
−5%	114	228	456	570	2280	3952	4560	6840	11846	12540	13110	13680
−7½%	111	222	444	555	2220	3848	4440	6660	11535	12210	12765	13320
−10%	108	216	432	540	2160	3744	4320	6480	11223	11880	12420	12960

TO PROPERLY USE CHART: Read actual incoming supply voltage, then find nominal voltage rating, under that rating find closest value to actual reading taken, read across to the left to the "Proper Tap" and connect.

THREE PHASE SUPPLY EMPLOYING THREE SINGLE PHASE TRANSFORMERS

FIG. 1

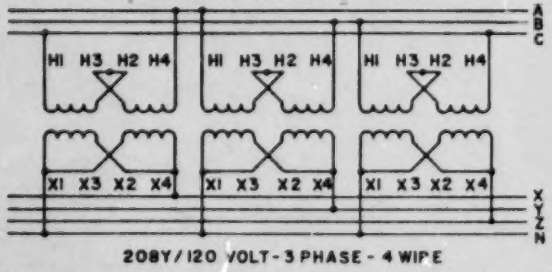
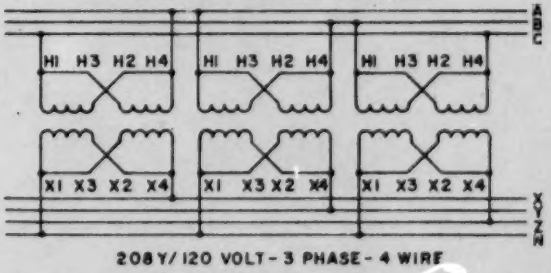
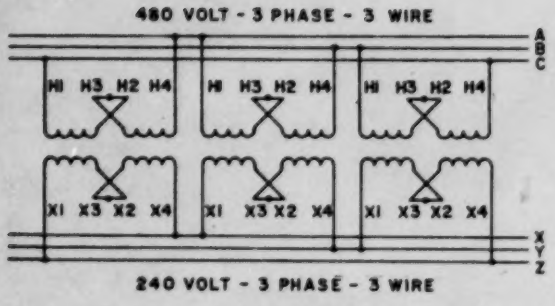


FIG. 2



Three dual wound transformers connected Δ-Y for three phase 480Δ-208Y/120 volts in Figure 1, and 240Δ-208Y/120 volts in Figure 2. Total KVA is the sum of the three.

FIG. 3



Three dual wound transformers in a Δ-Δ connection, 480Δ-240Δ volts. Total KVA is the sum of the three units.

FIG. 4

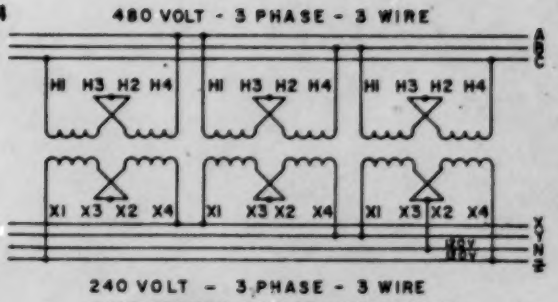
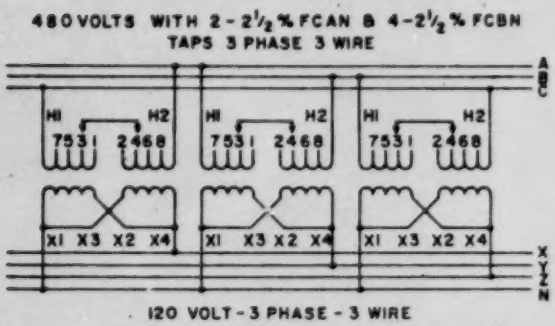


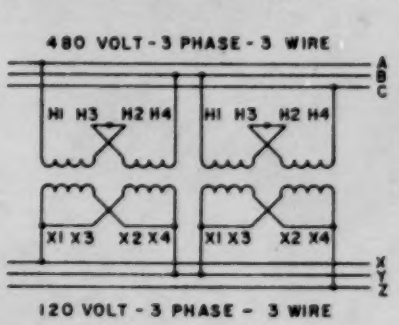
Fig. 4 is identical to fig. with the additional tap on only one leg of one unit connected for 120 volt single phase supply.

FIG. 5



Three single wound primary units connected 480Δ-208Y/120 volts.

FIG. 6



Two dual wound primary units in open delta connection. KVA output is 86% of the sum of the two.

TRANSFORMER FULL LOAD CURRENT TABLES

Rated Line Amperes for KVA and Voltages of Single Phase Transformers

Table 1

KVA Rating	120V	208V	240V	277V	480V	600V	2400V	4160V	4800V	7200V	13200V
	AMPERES										
1	8.33	4.81	4.17	3.61	2.08	1.67	–	–	–	–	–
1.5	12.5	7.21	6.25	5.42	3.13	2.50	–	–	–	–	–
2	16.7	9.62	8.33	7.22	4.17	3.33	–	–	–	–	–
3	25.0	14.42	12.5	10.83	6.25	5.00	1.25	.721	.625	.417	.227
5	41.7	24	20.8	18.1	10.4	8.33	2.08	1.2	1.04	.694	.379
7.5	62.5	36.1	31.3	27.1	15.6	12.5	3.13	1.8	1.56	1.04	.568
10	83.3	48.1	41.7	36.1	20.8	16.7	4.17	2.4	2.08	1.39	.758
15	125	72.1	62.5	54.2	31.3	25.0	6.25	3.61	3.13	2.08	1.14
20	167	96.2	83.3	72.2	41.7	33.3	8.33	4.81	4.17	2.78	1.52
25	208	120	104	90.3	52.1	41.7	10.4	6.01	5.21	3.47	1.89
30	250	144	125	108	62.5	50	12.5	7.21	6.25	4.17	2.27
37.5	313	180	155	135	78.0	62.5	15.6	9.01	7.80	5.21	2.84
50	417	240	208	181	104	83.3	20.8	12	10.4	6.94	3.79
75	625	361	313	271	156	125	31.3	18	15.6	10.4	5.68
100	833	481	417	361	208	167	41.7	24	20.8	13.9	7.58
150	1250	721	625	542	313	250	62.5	36.1	31.3	20.8	11.4
167	1392	803	695	603	348	278	69.6	40.1	34.8	23.2	12.7
200	1667	962	833	722	417	333	83.3	48.1	41.7	27.8	15.2
250	2083	1202	1042	903	521	417	104	60.1	52.1	34.7	18.9
333	2775	1601	1388	1202	694	565	139	80	69.4	46.3	25.2
500	4167	2404	2083	1805	1042	833	208	120	104	69.4	37.9

Rated Line Amperes for KVA and Voltages of Three Phase Transformers

Table 2

KVA Rating	208V	240V	480V	600V	2400V	4160V	4800V	11200V	26000V	35000V	46000V
	AMPERES										
3	8.34	7.23	3.61	2.89	.723	.417	.361	.131	–	–	–
6	16.6	14.4	7.2	5.8	1.46	.83	.72	.26	–	–	–
9	25	21.7	10.8	8.67	2.17	1.25	1.08	.394	–	–	–
15	41.7	36.1	18.1	14.5	3.61	2.09	1.81	.657	–	–	–
20	55.6	48.2	24.1	19.3	4.82	2.78	2.41	.876	–	–	–
25	69.5	60.2	30.1	24.1	6.02	3.48	3.01	1.09	–	–	–
30	83.4	72.3	36.1	28.9	7.23	4.17	3.61	1.31	–	–	–
37.5	104	90.3	45.2	36.1	9.03	5.22	4.52	1.64	–	–	–
45	125	108	54.2	43.4	10.8	6.26	5.42	1.97	–	–	–
50	139	120	60.2	48.2	12	6.96	6.02	2.19	–	–	–
60	167	145	72.3	57.8	14.5	8.35	7.23	2.63	–	–	–
75	208	181	90.3	72.3	18.1	10.4	9.03	3.28	–	–	–
100	278	241	120	96.3	24.1	13.9	12	4.38	–	–	–
112.5	313	271	135	108	27.1	15.7	13.5	4.93	–	–	–
150	417	361	181	145	36.1	20.9	18.1	6.57	–	–	–
200	556	482	241	193	48.2	27.8	24.1	8.76	–	–	–
225	625	542	271	217	54.2	31.3	27.1	9.85	–	–	–
300	834	723	361	289	72.3	41.7	36.1	13.1	–	–	–
400	1112	963	482	385	96.3	55.7	48.2	17.5	–	–	–
500	1390	1204	807	482	120	69.6	60.2	21.9	–	–	–
750	2084	1806	903	723	181	104	90.3	32.8	–	–	–
1000	2779	2408	1204	963	241	139	120	43.8	22.2	16.5	12.6
1500	4169	3613	1806	1445	361	209	181	65.7	33.3	24.8	18.8
2000	5558	4817	2408	1927	482	278	241	87.6	44.5	33	25.1

NAME _____ LESSON B-4

DATE _____ WORKSHEET

SINGLE PHASE TRANSFORMERS

1. Match the capital letter on each of the following schematic drawings to the proper transformer description:

_____ Transformer having single primary winding and dual secondary windings, with secondary connected in series.

_____ Transformer having dual primary connected in series and dual secondary connected in parallel.

_____ Transformer having dual primary connected in series and dual secondary connected in series.

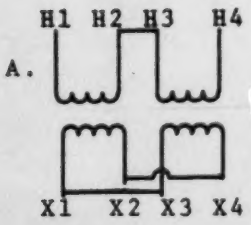
_____ Transformer having single primary and secondary windings.

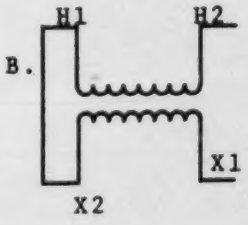
_____ Transformer connected additive polarity.

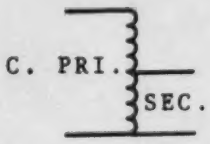
_____ Transformer connected subtractive polarity.

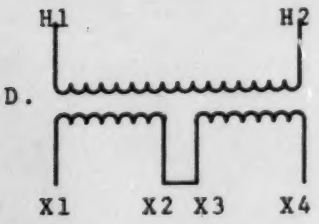
_____ Autotransformer.

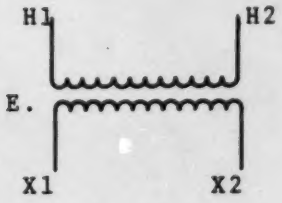
_____ Transformer having dual primary connected in parallel and single secondary windings.

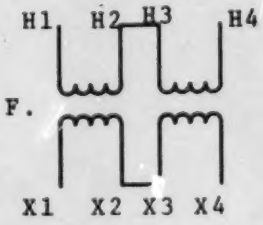


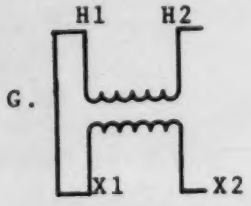


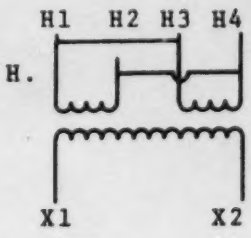












2. The autotransformer is the most efficient and effective means of increasing or decreasing voltage. True/False _____

3. Single phase transformers on an unbalanced 3-wire system should be designed in order for each transformer to: (Circle answer.)

   a. be at least 5 KVA each

   b. have two ground wires

   c. be neutral, and black in color

   d. be equal to twice the load on the most heavily loaded of the two side circuit

4. Two phase, four wire systems transformers should be designed for line voltage and line current. True/False _____

5. Coils of either a single phase or a three phase transformer may be connected for operating as an autotransformer. True/False _____

6. National Electrical Code Article 210-9 covers: (Circle answer.)

   a. Three phase transformer branch circuits

   b. Autotransformer branch circuits permitted

   c. Single phase transformers branch circuits

NAME _____ LESSON B-5

DATE _____ WORKSHEET

THREE-PHASE TRANSFORMERS

1. What three factors make the installation of a three-phase transformer more advantageous than a bank of single phase transformers operating as a unit?

   a. _____

   b. _____

   c. _____

2. The voltage on the windings of a delta-delta connected transformer is equal to the _____ voltage.

3. The current on the winding of a delta-delta connected transformer is .58 times the line _____.

4. The voltage on the windings of a wye-wye connected transformer is equal to .58 times the line _____.

5. The current on the windings of a wye-wye connected transformer is equal to the _____ current.

6. What two basic installation precautions should be followed in mounting any transformer?

   a. _____

   b. _____

7. List two reasons for connecting the primary and secondary neutrals in wye-wye connected transformers:

   a. _____

   b. _____

8. A bank of three transformers connected wye-wye are to supply a load of 300 KVA. What is the size of each transformer?

   _____

9. A three-phase transformer is three _____ phase transformers connected in _____ and enclosed in a single housing.

10. What type transformer connection is the least expensive to install?
_____

11. In a delta-wye connected transformer bank, the secondary voltage is _____ larger than a delta-delta connected bank.

12. A step-up transformer _____ the voltage and _____ the current.

13. List two disadvantages of the open delta transformer connection:

    a. _____

    b. _____

14. In an open delta bank connection, the transformer's capacities must be _____% larger than delta or wye connected bank.

15. Taps on a transformer are used for _____ the voltage by a small amount - usually 2 1/2 % per step.

NAME _____ LESSON B-6

DATE _____ WORKSHEET

FIXED ELECTRIC SPACE HEATING

1. What are the eight main types of fixed electric space heating equipment?

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

   f. _____

   g. _____

   h. _____

2. The size of branch-circuit conductors supplying fixed electric space heating equipment shall be sized on the basis of _____% of the total connected load.

3. The overcurrent protective device for the above branch circuit conductor must be sized for _____% of the total connected load.

4. How would you know if an electric heater was approved for installation in a damp location or mounted directly on a combustible surface?

   _____

   _____

5. An individual branch circuit may supply _____ ampacity circuit for fixed space heating equipment.

6. If the branch circuit supplies two or more outlets for fixed electric space heating equipment, the size is limited to _____ amperes.

7. A thermostat with an "OFF" position which does not open all ungrounded conductors can be used as the heater disconnect. Yes/No _____
   Give the Code section for your answer. _____

8. The maximum overcurrent protection for resistance-type space heating equipment is _____ amperes. The maximum load shall not exceed _____ amperes.

9. The maximum overcurrent protection for infrared electric space heating equipment is _____ amperes.

10. Match the identifying colored lead wires with the proper voltage of heating cable.

Red _____	(a)	120 volts
Yellow _____	(b)	208 volts
Blue _____	(c)	240 volts
Brown _____	(d)	277 volts

11. Is it necessary to apply a correction factor for wiring above a heated ceiling which has two inches of insulation? Yes/No _____ Give the Code section for your answer. _____

12. Each unit of fixed electric space heating equipment shall be marked with the rating in volts and _____,or volts and _____.

13. Heat panels and ceiling cables shall be at least ____ inches from the edge of surface mounted fixture outlet boxes and ____ inches from recessed fixtures and ventilating openings.

14. The fan and duct heater circuits must be _____ so the movement of air across the heater is assured.

15. The duct heater disconnect must be ____ or within _____ of the duct heater controller.

NAME _____ LESSON B-7

DATE _____ WORKSHEET

OUTDOOR DE-ICING AND SNOW MELTING EQUIPMENT

1. Eave, gutter, and down-spout de-icing cables are covered in Article _____ of the N. E. Code. What section would it be covered under?

   _____

2. The load for de-icing and snow melting equipment is considered as _____. This means the overcurrent protective device and the branch circuit conductor must be sized for _____% of the load.

3. The maximum branch circuit overcurrent protective device for de-icing and snow melting equipment is _____ amperes. Give the N. E. Code section for your answer. _____

4. Can the non-heating leads of de-icing and snow melting equipment be shortened? Yes/No _____ Give the N. E. Code section for your answer. _____ Is this different from indoor ceiling and floor cable installations? Yes/No _____ Give the N. E. Code section for your answer. _____

5. Under what conditions can an automatic snow melting control device be considered as the circuit disconnecting means?

   a. _____

   b. _____

   c. _____

   _____

6. The nominal covering for embedded cables is _____ inches below the surface.

7. The Code requires cables to be tested before _____. The careful electrician will test the cable before installation, before _____, and _____ covering.

8. What six basic installation rules should be followed for installing de-icing and snow-melting equipment?

   a. _____

   b. _____

(over)

c. _____

d. _____

e. _____

f. _____

9. What Code section covers Branch-Circuit requirement on fixed electric heating for pipeline and vessels. _____.

10. When using a temperature - controlled switching device which indicates an off position. Is it required to open all ungrounded conductors? _____ Give code section. _____.

11. Do the metal parts of electric heating equipment for pipe line and vessels need to be grounded. _____ Give code section. _____

NAME _____ LESSON B-8

DATE _____ WORKSHEET

GENERAL INSTALLATION REQUIREMENTS

1. What does Article 110 of the National Electrical Code cover?

   _____

2. The Code requires that conductors and equipment be approved. What is meant by approved? _____

   _____

3. Match Column A with Code Numbers in Column B.

Column A	Column B
_____ (a) Manditory Rules	(1) 110-6
_____ (b) Circuit Voltage	(2) 110-8
_____ (c) Conductor Gages	(3) 110-4
_____ (d) Wiring Methods	(4) 110-1
	(5) 110-9

4. Give Code section that tells how all equipment shall be installed.

   _____ How shall it be installed? _____

   _____

5. TRUE OR FALSE - Mark T or F on line after statement and give Code references.

   (a) All electrical equipment shall be identified by the manufacturer's name or trademark. _____ Reference _____

   (b) When the wiring system is completed, all wiring shall be free from short circuits and grounds. _____ Reference _____

   (c) The Code permits you to put a shelf (for storage purposes) across the front of a panel if it is a removable type.
   _____ Reference _____

   (d) All conductors shall be spliced or joined with approved splicing devices. _____ Reference _____

   (e) The Code permits the use of wooden pegs driven into holes in masonry walls to fasten electrical equipment to the wall. _____
   Reference _____

(f) If equipment operates at more than 50 volts, and not more than 600 volts is elevated at least 8 feet above the floor, it does not need to have a guard over "live parts." _____ Reference _____

NAME _____ LESSON B-9

DATE _____ WORKSHEET

GROUNDED CONDUCTORS

1. All interior wiring systems shall have a grounded conductor. How is this conductor identified? _____

2. In the following wiring methods, how is the Grounded Conductor identified?

   a. MI Cable _____

   b. Conductors # 6 or smaller in conduit _____

   _____

   c. Conductors larger than # 6. _____

   _____

   d. A 4-wire Delta-connected secondary - the mid-point of one phase grounded to feed lighting loads. How shall the "High Leg" be marked at the point of connection if the neutral conductor is present? _____

3. In cable wiring, what section of the N. E. Code allows the identified conductor (white wire) to be used as the "return conductor" from the switch to the outlet? _____

4. Grounded conductor shall be connected to _____ - _____ terminal.

5. Identified conductor shall be connected to identified _____ colored terminal to screw-shell.

6. Grounded terminal shall be identified by _____ _____ coating.

7. The equipment grounding conductor terminal on the receptacle shall be _____ color.

8. The grounded circuit conductor terminal on the receptacle shall be _____ color.

9. Terminals on fixed _____ or portable _____ do not require identification.

10. Switching devices in each tapped circuit shall have a pole in each _____ conductor and the poles shall operate _____.

11. Can an autotransformer be installed to set up a 208 volt 1 Ø circuit for a 240 volt 1 Ø range? Yes/No _____ Give the N.E. Code Article to justify your answer. _____

NAME _____ LESSON B-10

DATE _____ WORKSHEET

GROUNDING

1. List two types of grounds used in an interior wiring system.

   a. _____

   b. _____

2. The _____ ground connects the non-current-carrying metal parts of the wiring system or equipment to _____.

3. In interior wiring systems, the _____ conductor shall be grounded.

4. Bonding jumpers shall be used to connect isolated equipment to _____ equipment.

5. The minimum copper grounding conductor for an A.C. system shall be No. ___ AWG.

6. The maximum copper grounding conductor required for an A.C. system is No. ____ AWG.

7. The minimum copper grounding conductor for an A.C. system with 250 MCM service entrance conductors shall be No. ____ AWG.

8. The minimum copper equipment ground conductor for a 60-ampere circuit shall be No. ___ AWG.

9. The resistance of made electrodes shall not exceed _____ ohms.

10. The minimum length of buried metallic water piping system permitted as a grounding electrode shall be _____ feet.

11. In general, underground water pipes have a resistance to ground of less than _____ ohms.

12. Splice connections on the _____ conductor is not permitted.

13. The equipment ground conductor shall be _____ color or _____.

14. In general metal enclosures for conductors shall be located a minimum of ____ feet from lightning rod grounding conductors.

15. Switchboard frames shall be _____ regardless of _____.

16. All portable tools shall be _____.

17. Service entrance conduit shall be _____.

18. A grounding conductor in cord shall be provided for cord-connected _____ equipment.

19. Metal frame constructed building shall be _____.

20. Frames of electric ranges and clothes dryer shall be _____.

21. List at least five approved types of grounding electrodes.

a. _____

b. _____

c. _____

d. _____

e. _____

NAME _____ LESSON B-11

DATE _____ WORKSHEET

BRANCH CIRCUITS

1. What Article covers branch circuits supplying lighting or appliance load or a combination of such loads? _____

2. Where conductors of different systems are installed in the same gutter or raceway, handling more than one identified conductor, how shall they be marked? _____
_____ Reference _____

3. What amount of voltage drop is permitted on power, heating, lighting, or combination Branch Circuits? _____ reference _____ List Code Section.

4. (a) What section of the Code covers ground-fault circuit protection on 15 and 20 ampere receptacle outlets on single phase circuit at construction sites? _____ (b) When does this become mandatory? _____.

5. Would a fixed room divider, bar-type counters count in the 6 foot rule for recptacles? Yes/No _____ Code Section Reference, _____.

6. There have been changes made in the Requirements for Receptacles in Kitchens and Dining Room areas. What are the requirements now? Reference _____. Remarks _____
_____.

7. Does the Code prohibit the use of a conductor having a green covering for internal wiring of equipment? Yes/No _____ Code Section Reference _____.

8. Give minimum size copper conductor for the following branch circuit classification (75°C).

   (a) 15 ampere branch circuit _____
   (b) 20 ampere branch circuit _____
   (c) 30 ampere branch circuit _____
   (d) 65 ampere branch circuit _____

9. The Code requires additional receptacles above the 200 watts per linear ft. in show window.

(a) Give Section _____

(b) Where are they located? _____

_____

10. What is a multiwire branch circuit? _____

_____ Reference Code _____

NAME _____ LESSON B-12

DATE _____ WORKSHEET

APPLIANCES

1. What is meant by:

   a. Fixed appliance? _____

   _____

   b. Portable appliance? _____

   _____

   c. Stationary appliance? _____

   _____

2. What are the Branch Circuit requirements for small appliances in a residence? _____

3. Does the Code require you to put a laundry circuit in all dwellings? _____. Give Code section to back up answer. _____

4. In calculating the feeder load, are you allowed to apply demand in table 220-11 to the small appliance load?

5. It it permissible to load a circuit to its capacity with portable or stationary appliances? _____

6. What would be the feeder load for five ranges rated at 11.5 kW each?

   _____

7. What would be the feeder load for the same 5 ranges if the rating was 13 kW each.

8. When there is a protective device rating marked on appliance, is it permissible to use a larger branch circuit overcurrent device?

   _____

9. Does the Code permit the use of flexible cord on fixed appliances? _____. Give Code section _____

10. Given a branch circuit supplying a single nonmotor-operated appliance and rated at 16.7 amperes or more, what is the maximum rating of the overcurrent device? _____. Code Reference _____

NAME _____ LESSON B-13

DATE _____ WORKSHEET

FEEDERS AND BRANCH CIRCUIT CALCULATIONS

1. Name the five basic items that should be included in a feeder diagram.

   (a) _____

   (b) _____

   (c) _____

   (d) _____

   (e) _____

2. Give Unit Load per square ft. for General Lighting Load that applies to the following:

	Answer	References
(a) Banks	_____	_____
(b) Court Rooms	_____	_____
(c) Office Buildings	_____	_____
(d) Dwellings (Other than Hotels)	_____	_____
(e) Schools	_____	_____
(f) Restaurants	_____	_____

3. How many circuits would be required for General Lighting in a dwelling having 2100 square ft.? _____. Give Code Section Reference _____

4. When calculating load for a dwelling, is the demand factor applied to the 2 kitchen and laundry circuits? _____

   _____

   Reference _____

5. When computing the square footage of a building for a general lighting load, what dimensions are used? _____ Code Section Reference _____

6. Find the minimum size lighting feeder (THW) Copper for an office building 6 floors, 75 feet by 125 feet each. The service is a 4-wire 3 phase 120/208 volts.

7. Give feeder load demand for the following: [Use Table 220-11]

   (a) Restaurants _____

   (b) Schools _____

   (c) Stores _____

   (d) Warehouse Storage _____

   _____

   (e) Banks _____

   (f) Courtrooms _____

8. Calculate the minimum service for a dwelling of 1800 square feet, having 12 kw range, 5 kw water heater, 1.5 kw dishwasher, 5 kw dryer, 5 - 1.5 kw space heaters, and 3 HP 230 V air conditioning units. (Use optional method - 220-30) Voltage 115/230 volts, single phase. References _____ _____ _____

9. Give feeder kw load for twelve (12) ranges rated at 11 kw each.
   _____ kw Reference _____

SERVICES FOR A TYPICAL DWELLING

A typical application for a 115/230 volt, single-phase, three wire service installation in a single family dwelling will be considered. It is the intent to give the apprentice the fundamental rules of the National Electrical Code insofar as they concern the calculations that affect the service entrance switch, service entrance conductors, and grounding. The branch circuits supplying the various items of electrical equipment will be discussed briefly. Since the metering of the electrical space heating equipment as well as electric water heaters varies with different power companies, the apprentice should check the requirements in the area.

The building under consideration will be a three-bedroom residence with an area of 1500 square feet.

A. The following appliances are scheduled for this home:

1. 3-kw water heater
2. 4.7-kw clothes dryer
3. 8 ampere 230-volt air conditioner
4. 11.1 ampere 115-volt dishwasher
5. 4-kw wall-mounted oven
6. 6-kw counter-mounted cooking unit
7. 7.5 ampere 115-volt garbage disposal
8. 12-kw space heating unit in each of 6 rooms

B. Calculations:

1. Determine the Number of Lighting Circuits

Calculate the load based on the "watts per square foot" method.
1500 sq. ft. x 3 watts per sq. ft. = 4500 watts

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{4500}{115} = 39.1 \text{ or } 40 \text{ amperes}$$

Generally, 15-ampere lighting circuits are installed in residential buildings using No. 14 AWG conductors. Some electrical specifications require No. 12 AWG conductors as a minimum on all circuits. Then $\frac{40}{15}$ = 2 plus or 3

Note: In a residence of this type, there may be as many as 60 outlets. Most electricians prefer to limit the number of outlets per circuit to 8 or 10, thus there would be 6 circuits installed.

2. Small Appliances

Most electricians prefer to run three 20 ampere circuits for small appliances to be used in the ktichen, laundry, pantry, dining room,

and breakfast room areas. It is a code requirement to install a separate 20 ampere circuit for the laundry outlet and divide the outlets in the kitchen and dining room area between the other 20 ampere circuits. The use of No. 12 wire instead of No. 14 wire to minimize the voltage drop, improves the performance of the appliances and lessens the danger of overload.

3. Clothes Dryer

The electric clothes dryer is rated 4.7 kw at 230 volts. The load value in watts is 4700.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{4700}{230} = 20.4 \text{ amperes}$$

The circuit to the dryer will be a 30 ampere 115/230 volt, 3 wire circuit of two No. 10 AWG conductors and one No. 12 AWG for the neutral conductor. The neutral may be smaller than the phase wires because it carries only the current of the motor and the light.

4. Air Conditioning

The load is 8 amperes x 230 volts = 1840 watts. It will be connected to a 15 ampere, 230 volt circuit with No. 14 AWG conductors. Circuits for air conditioners must conform to the provisions of the Code.

5. Dishwasher

The load is 11.1 amperes x 115 volts = 1276 watts. This unit will be supplied by a separate 15-ampere circuit using No. 14 AWG wire.

6. Garbage Disposal

The load is 7.5 amperes x 115 volts = 852 watts. This circuit will be supplied by a separate 15-ampere circuit which requires No. 14 AWG wire.

7. Wall Mounted Oven

The oven is rated 4-kw at 115/230 volts and will be connected to a separate circuit. The load value in watts is 4000.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{4000}{230} = 17.4 \text{ amperes}$$

According to the table No. 12 AWG conductor may be used for this circuit. NEC - 250-260, Ground with No. 10.

8. Counter-Mounted Cooking Unit

The surface cooking unit is rated 6 kw at 115/230 volts and will be connected to a separate circuit consisting of three No. 10 AWG conductors supplied by a 30-ampere, 2 pole overcurrent device.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{6000}{230} = 26 \text{ (approx.) amperes}$$

Note: The Code permits the use of one 50-ampere circuit to supply these two units, provided the individual taps to the 50-ampere circuit are not longer than necessary for servicing.

9. Electric Space Heating

Six 2 kw electric space heating units will be installed with a thermostat which provides individual room control for heating purposes. Also, it is necessary that there be four or more individually controlled electric space heating units in order to apply certain demand factors permitted by the Code used in calculating service-entrance capacity. Each of these units is rated at 2 kw and 230 volt circuit.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{2000}{230} = 8.7 \text{ amperes}$$

Each separate unit will be connected to a separate 15-ampere, 230 volt circuit using No. 14 AWG wire.

10. Water Heater

The water heater in this residence is rated at 3-kw.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{3000}{230} = 13 \text{ amperes}$$

Connected for unlimited demand, the maximum current would be 13 amperes and No. 14 AWG could be used. However, for a load that so closely approaches the maximum current-carrying capacity of No. 14 AWG, most electricians would install No. 12 AWG (20 ampere) and connect it to a 15 ampere, 230 circuit.

Note: Consult local utility for proper connections of water heaters because some require a special "off-peak" meter and others use special methods to cover the power consumption.

11. Ground fault circuit protectors are required for all outside outlets and in each bathroom. These can either be G.F. circuit breakers in the panel or G.F. receptacles at the outlet.

SUMMARY OF SERVICES FOR 1500 SQ. FT. DWELLING

Use of Circuits	No. of Circuits	Rating		Wire Size
		Volts	Amperes	AWG
General Lighting	6	115	15	14
Small Appliances	3	115	20	12
Garbage Disposal	1	115	15	14
Dishwasher	1	115	15	14
Dryer	1	115/230	30	10
Oven	1	115/230	20	12
Counter Cook Top	1	115/230	30	10
Air Conditioner	1	230	15	14
Water Heater	1	230	15	12
Space Heat	6	230	15	14

Service Entrance Switch

To accomodate the number of circuits listed in the summary, a 200-ampere panel will be installed. This panel will contain all of the required branch circuits plus a 200-ampere main pullout in one enclosure. This type of enclosure is approved by Underwriters' Laboratories, Inc. and should meet the Code requirements in most localities.

Ground Connection

The Code requires interior-alternating-current systems to be grounded. This is done by running a wire from the neutral connection in the main service switch or meter to a water pipe. Exceptions to the rule are specified in the Code.

NAME _____ LESSON B-14

DATE _____ WORKSHEET

SERVICES

1. What does the service consist of? _____
_____ Reference _____

2. (a) What is meant by service drop conductors? _____
_____
_____
_____

(b) What is meant by service-entrance conductors? _____
_____
_____
_____

3. List six conditions which permit more than one service drop to a building.

References

(a) _____ _____

(b) _____ _____

(c) _____ _____

(d) _____ _____

(e) _____ _____

(f) _____ _____

4. True or False - Give answer T or F and explain or give reference.

_____ (a) It is permissible to run a bare service conductor in conduit on exterior of a building. Reference _____

_____ (b) It is permissible to splice service entrance conductors. Reference _____

_____ (c) The clearance of service drops across private driveway is 10 feet. Reference _____

_____ (d) The point of attachment to a building for service drops shall always be 10 feet. Reference _____

_____ (e) The Code permits you to use six main disconnect switches on one service as long as they are grouped together. Reference _____

___ (f) Each ungrounded service conductor must have overcurrent protection. Reference _____

___ (g) An enclosed service disconnecting means should be externally operable. Reference _____

___ (h) Ground-fault protection is required on services rated at 1,000 amperes or more. Reference _____

___ (i) Fire pumps require overcurrent protection.

___ (j) Drip loops should be formed in each service conductor to prevent the entrance of moisture.

5. Must there be means to disconnect the grounded conductor from the interior wiring, at the service disconnect switch? _____
Give Code Section Reference. _____

6. (a) Where are seals required on the underground service raceway?
_____
Give Code Section Reference. _____

(b) Are seals required on spare underground service raceway? _____
Reference _____

7. Service equipment enclosures _____ be grounded. (Should or Shall)
Give Code section. _____

8. Does the code require the disconnecting means to be inside the building it is to service? _____ Give Code section to back up your answer. _____

9. On a six family apartment building, is it permissible to locate all main disconnects in one apartment? _____ Give Code section to back up your answer. _____

10. Define a Master Service. _____
_____
Give your reference. _____

NAME _____ LESSON B-15

DATE _____ WORKSHEET

TEMPORARY SERVICES

True-False Questions--Circle correct answer and give reference or reason for your answer.

1. Temporary wiring methods are in a class by themselves. True/False.

   Reference or Reason _____

2. Article 305 of the N. E. Code sets the requirements for temporary wiring. True/False.

   Reference or Reason _____

3. Temporary wiring can only be used for 90 days for any type temporary installation. True/False.

   Reference or Reason _____

4. Ground-fault circuit protection is required for all 15 and 20 ampere receptacle outlets. True/False.

   Reference or Reason _____

5. Can a two-wire 120 volt 15 ampere receptacle be used as an outlet for a 1/4 H. P. drill motor on a construction site? Yes/No.

   Reference or Reason _____

6. Does every branch circuit which supplies receptacles or fixed equipment have to contain a separate equipment grounding conductor? Yes/No.

7. Explain your answer to the question above. (No. 6)

   _____

   _____

   _____

   _____

8. List 4 ways of running a branch circuit for temporary power and lighting.

(a) _____

(b) _____

(c) _____

(d) _____

9. Can the equipment grounding conductor be bare when it is installed with open wiring at the ceiling and supported every 10 feet. Yes/No.

Reference or Reason _____

10. A 3/4 inch diameter by 10 foot copper-clad ground rod is approved as an earth return for a receptacle which has no equipment grounding conductor in the circuit feeding the receptacle. True/False.

Reference or Reason _____

11. Overcurrent protective devices should be sized to the: (Choose best answer.)

____ (a) Ampacity of the load.

____ (b) Ampacity of the conductors.

____ (c) Ampacity of the load plus 25%.

12. Three phase concrete block saws do not have to be grounded. True/False.

Reference or Reason _____

13. Can the grounding electrode conductor for a temporary wiring service be aluminum? Yes/No.

14. Give the Code section to prove your answer to the above question.

_____

15. Feeders and branch circuits shall originate in an approved distribution center or panelboard. What does the word "approved" cover?

(a) _____

_____

(b) _____

_____

(c) _____

_____

NAME _____ LESSON B-16

DATE _____ WORKSHEET

OUTSIDE BRANCH CIRCUITS

1. Where conductors are in cable or raceways and within 10 feet of a building or any other structure, what type of insulation shall be used?

   a. _____

   b. _____

   c. _____

2. Give the minimum size conductors for the following:

   a. Overhead spans _____

   _____

   b. Festoon lighting _____

   _____

   c. Over 600 volts _____

   _____

3. What is minimum separation of conductors exposed to weather? Also support bracket separation? _____

   (1) _____

   (2) _____

   (3) _____

   _____

4. What are the minimum clearances in feet of open conductors not over 600 volts?

   a. Above finish grade _____

   b. Residential driveways _____

   c. Parking lots not subject to truck traffic _____

   d. Public streets _____

   e. Over roof _____

5. How shall open conductors be supported? _____

   _____

6. What is the maximum branch circuit voltage supplying lamp holders or lighting fixtures mounted on outside of buildings or on poles or structures for area illumination of residential, commercial, or industrial property?

Motor enclosures

(NEMA designations)*

OPEN

General purpose: Ventilating openings permit passage of external cooling air over and around the windings of the machine.

Drip-proof: Ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle from 0 to 15 degrees downward from the vertical.

Splash-proof: Ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle not greater than 100 degrees downward from the vertical.

Guarded: Openings giving direct access to live or rotating parts (except smooth shafts) are limited as to size by the design of the structural parts or by screens, grills, expanded metal, etc., to prevent accidental contact with such parts.

Semi-guarded: Part of the ventilating openings, usually in top half, are guarded as in a "guarded machine," but others are left open.

Drip-proof fully guarded: A drip-proof machine with ventilating openings as in a "guarded machine."

Externally ventilated: A machine which is ventilated by means of a separate motor-driven blower mounted on machine enclosure. Mechanical protection may be as defined above.

Pipe ventilated: Openings for admission of ventilating air are so arranged that inlet ducts or pipes can be connected to them.

Weather-protected: Type I: Ventilation passages are so designed as to minimize the entrance of rain, snow and airborne particles to the electrical parts. Type II: Ventilating passages at intake and discharge are so arranged that high-velocity air and airborne particles blown into the machine by storms or high winds can be discharged without entering the internal ventilating passages leading directly to the electrical parts.

Encapsulated windings: An alternating-current squirrel-cage machine having random windings filled with an insulating resin which also forms a protective coating.

Sealed windings: An alternating-current squirrel-cage machine making use of form-wound coils and having an insulation system which, through the use of materials, processes, or a combination of materials and processes, results in a sealing of the windings and connections against contaminants.

TOTALLY ENCLOSED

Nonventilated: Enclosure prevents free exchange of air between inside and outside of case, but not airtight.

Fan-cooled: Equipped for exterior cooling by means of a fan or fans, integral with machine, but external to the enclosing parts.

Fan-cooled guarded: All openings, giving direct access to fan, are limited in size by design of structural parts or by screens, grills, expanded metal, etc., to prevent accidental contact with fan.

Explosion-proof: Designed and built to withstand an explosion of gas or vapor within it and to prevent ignition of gas or vapor surrounding machine by sparks, flashes, or explosions which may occur within machine casing.

Dust-ignition-proof: Designed and built to exclude ignitable amounts of dust or amounts affecting performance or rating to prevent ignition of exterior dust on or in vicinity of enclosure.

Water-proof: Designed to exclude water applied in a stream from a hose except leakage is permitted around the shaft provided that water is excluded from oil reservoir and means of drainage is provided.

Pipe-ventilated: Openings so arranged that inlet and outlet ducts or pipes may be connected to them for the admission and discharge of ventilating air.

Water-cooled: Cooled by circulating water; the water or water conductors come in direct contact with the machine parts.

Water-air-cooled: Cooled by circulating air which, in turn, is cooled by circulating water.

Air-to-air-cooled: Cooled by circulating internal air through heat exchanger which, in turn, is cooled by circulating external air.

See NEMA Standards MG1-1.25.26.2 for additional details.

Basic motor insulation classes

Class A. Materials or combinations of materials such as cotton, silk and paper, when suitably impregnated or coated, or when immersed in a dielectric liquid such as oil. This class of material is falling into disuse.

Class B. Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests the total system can be shown to be capable of operating successfully on the machine under consideration (120°F-130°F).

Class F. Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests the total system can be shown to be capable of operating successfully on the machine under consideration (145°F-155°F).

Class H. Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, etc., with suitable bonding substances such as appropriate silicone resins. Other materials or combinations of materials may be included in this class if by experience or accepted tests the total system can be shown to be capable of operating successfully on the machine under consideration (165°F-180°F).

Motor enclosures
(NEMA designations)*

OPEN

General purpose: Ventilating openings permit passage of external cooling air over and around the windings of the machine.

Drip-proof: Ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle from 0 to 15 degrees downward from the vertical.

Splash-proof: Ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle not greater than 100 degrees downward from the vertical.

Guarded: Openings giving direct access to live or rotating parts (except smooth shafts) are limited as to size by the design of the structural parts or by screens, grills, expanded metal, etc., to prevent accidental contact with such parts.

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Sealed windings: An alternating-current squirrel-cage machine making use of form-wound coils and having an insulation system which, through the use of materials, processes, or a combination of materials and processes, results in a sealing of the windings and connections against contaminants.

TOTALLY ENCLOSED

Nonventilated: Enclosure prevents free exchange of air between inside and outside of case, but not airtight.

Fan-cooled: Equipped for exterior cooling by means of a fan or fans, integral with machine, but external to the enclosing parts.

Fan-cooled guarded: All openings, giving direct access to fan, are limited in size by design of structural parts or by screens, grills, expanded metal, etc., to prevent accidental contact with fan.

Explosion-proof: Designed and built to withstand an explosion of gas or vapor within it and to prevent ignition of gas or vapor surrounding machine by sparks, flashes, or explosions which may occur within machine casing.

Dust-ignition-proof: Designed and built to exclude ignitable amounts of dust or amounts affecting performance or rating to prevent ignition of exterior dust on or in vicinity of enclosure.

Water-proof: Designed to exclude water applied in a stream from a hose except leakage is permitted around the shaft provided that water is excluded from oil reservoir and means of drainage is provided.

Pipe-ventilated: Openings so arranged that inlet and outlet ducts or pipes may be connected to them for the admission and discharge of ventilating air.

Water-cooled: Cooled by circulating water, the water or water conductors come in direct contact with the machine parts.

Water-air-cooled: Cooled by circulating air which, in turn, is cooled by circulating water.

Air-to-air-cooled: Cooled by circulating internal air through heat exchanger which, in turn, is cooled by circulating external air.

*See NEMA Standards MG1-1.25.26.27 for additional details.

Basic motor insulation classes

Class A. Materials or combinations of materials such as cotton, silk and paper, when suitably impregnated or coated, or when immersed in a dielectric liquid such as oil. This class of material is falling into disuse.

Class B. Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests the total system can be shown to be capable of operating successfully on the machine under consideration (120°F-130°F).

Class F. Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests the total system can be shown to be capable of operating successfully on the machine under consideration (145°F-155°F).

Class H. Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, etc., with suitable bonding substances such as appropriate silicone resins. Other materials or combinations of materials may be included in this class if by experience or accepted tests the total system can be shown to be capable of operating successfully on the machine under consideration (165°F-180°F).

Controller enclosures
(NEMA designations)*

Type	Description	Application
1	General purpose	Indoors; atmospheric conditions normal. Provides protection against dust and light, indirect splashing—but is not dust-tight.
2	Driptight	Indoors; general-purpose enclosure; shields give protection from dripping liquids and dirt.
3	Weather-resistant (Weatherproof)	Outdoors; where exposed to rain or sleet.
4	Watertight	Outdoors; water or moisture excluded from splashing or direct stream.
5	Dust-tight	Indoors: prevents entry of dust into nonhazardous locations.
6	Submersible	For use where unit may be submerged in water.
7	Hazardous areas (Groups A-B-C-D)	For Class 1 locations containing hazardous gases; air-break contacts.
8	Hazardous areas (Groups A-B-C-D)	For use where gases are corrosive (similar to Type 7, but contacts are immersed in oil).
9	Hazardous areas (Groups E-F-G)	For use in Class II, Group E, F and G locations containing hazardous dusts.
10	Bureau of Mines	For use in coal mines.
11	Corrosion-proof	For use where exposed to corrosive acid or fumes.
12	Industrial	Protects against dirt, dust, lint, fibers, flyings and oil or coolant seepage; meets JIC electrical standards for industrial equipment.

* Last revised in 1956.

NAME _____ LESSON B-17

DATE _____ WORKSHEET

D.C. MOTORS AND GENERATORS

1. What are the three principal types of D.C. motors?

   a. _____

   b. _____

   c. _____

2. The reostat _____ the flow of current in starting a D.C. motor.

3. The speed of D.C. motors can be controlled by what two general classifications?

   a. _____

   b. _____

4. There are two types of electrodynamic drive control for D.C. motors. Name them.

   a. _____

   b. _____

5. The actual effective voltage in an armature of a D.C. motor is the _____ voltage less the _____.

6. The speed of a D.C. motor depends on:

   a. _____

   b. _____

   c. _____

7. Shunt motors are considered as _____ speed motors.

8. Series motors are considered as _____ speed motors.

9. The compound motor is a combination of the _____ motor and the _____ motor.

10. The direction of rotation of a D.C. motor can be reversed by reversing the _____ connections or the _____ connections.

11. A _____-_____ generator is used to charge batteries by the floating method of charge because it can produce a constant terminal _____ of from 0-110%.

12. To generate electricity, there must be a relative motion between a _____ and a _____ field.

13. In D. C. generators, the armature is always the _____. In most A. C. generators, the armature is _____.

14. A. C. generators are sometimes called _____.

15. A three-phase alternator has each phase displaced _____ degrees from each other.

16. In a 3 Ø "wye" or "star" alternator, the line voltage across any two line levels is the _____ _____ of the individual phase voltages. The line voltage is _____ times the phase voltage. Line and phase currents are _____.

17. In a 3 Ø "delta" alternator, the line voltages are _____ to the phase voltage, but the line currents will be equal to the _____ _____ of the phase currents. The line current will be _____ times the phase current.

NAME _____ LESSON B-18

DATE _____ WORKSHEET

SINGLE PHASE MOTORS

1. The starting _____ has a _____ resistance than the running winding of a split-phase motor, thus the interaction of the rotating magnetic field provides a starting _____ for the motor.

2. The purpose of the _____ _____ is to get a _____ _____ between the windings.

3. The angular phase displacement in a split-phase motor is approximately _____ to 30 degrees in time.

4. The _____ _____ opens the circuit to the starting winding as the rotor speed reaches approximately _____ percent of the synchronous speed.

5. Overheating of the winding insulation may be caused by _____ _____, _____ _____, and _____ _____ currents.

6. The standard direction of rotation is _____ as viewed from the _____ _____.

7. Two-speed split-phase motors have _____ sets of windings, ___ ___ for each speed.

8. The permanent-split capacitor motor has a ____ _____ torque.

9. There is no change in _____ in the permanent-split capacitor motor.

10. Permanent _____ _____ motors are used for fans and blowers.

11. Repulsion motors have a very _____ torque.

12. As the load increases in the repulsion motor, the _____ decreases.

13. Repulsion motors may be reversed by shifting _____ to the _____ side of neutral plane.

14. In a repulsion motor, the _____ poles are repelled by the _____ poles causing the _____ to rotate.

15. The _____ motor operates on A.C. or D.C. circuits.

16. The _____ is connected in series with the _____ in a universal motor.

17. In a universal motor operating on an A.C. source, the _____ windings are arranged so the _____ of the magnetic poles changes causing the _____ to turn.

18. List two types of universal motors:

    (a) _____

    (b) _____

19. The _____ universal motor has an extra winding embedded in the poles of the starter.

20. The _____ universal motor is a low-horsepower motor operating at _____ speeds.

21. A _____ must be installed in series with one of the power lines to the concentrated-pole universal motor at speeds less than _____ RPM.

22. List three methods used to control the no-load speeds of the universal motor:

    (a) _____

    (b) _____

    (c) _____

NAME _____ LESSON B-19

DATE _____ WORKSHEET

THREE PHASE MOTORS

1. List the three major types of three-phase motors:

   (a) _____

   (b) _____

   (c) _____

2. Squirrel-cage motors do not have a _____ _____ torque.

3. In a three-phase motor, the windings are _____ electrical degrees apart.

4. List two methods of connecting a three-phase motor stator to a three phase power source.

   (a) _____

   (b) _____

5. The _____-_____ motor operates on the induction principle.

6. The squirrel-cage motor never reaches _____ speed.

7. List the four conditions which regulate the speed of a squirrel-cage motor:

   (a) _____

   (b) _____

   (c) _____

   (d) _____

8. The difference between the speed of the rotating field and the rotor is called _____.

9. The squirrel-cage motor is considered to be a _____ - _____ type.

10. The currents produced in the rotor are fed to _____ _____ of a wound-rotor motor.

11. In a wound-rotor motor, the starting _____ and current, _____ load and _____ of the motor can be controlled.

12. In a wound-rotor motor, loss of speed results in a _____of _____.

13. The wound-rotor motor is used for equipment having constant _____ _____ and _____ _____ up to full-rated load.

14. The rotation of a three-phase motor may be reversed by _____ any _____ _____ to the motor.

15. The two windings of three-phase induction motors are located in the _____ and _____.

16. The _____ windings are embedded in slots.

17. The rotor windings may be of the _____ - _____ or _____ - _____ type.

18. List two important characteristics of a synchronous motor:

    (a) _____

    (b) _____

19. What are the four main types of electric motor braking?

    (a) _____

    (b) _____

    (c) _____

    (d) _____

20. What type motor is used to transmit information in the form of electrical signals? _____

NAME _____ LESSON B-20

DATE _____ WORKSHEET

MOTOR CIRCUITS

1. Explain what the N. E. Code means when it specifies that some equipment shall be "in sight from" another equipment.

_____

_____

2. List the information that should be on the name plate of a motor.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

3. What are the three types of motor circuit conductors? Give the N.E. Code Section for each type.

	Types	Code Section
a.	_____	_____
b.	_____	_____
c.	_____	_____

4. Draw a one line Schematic Diagram showing three motors connected. Show all disconnects, feeders, branch circuits, and overcurrent protection. Give the N. E. Code Section for each provision. Show or list the Branch Circuits located less than 25 feet from main.

(Space for answer on next page.)

4. (Answer)

5. Match the Code Section by placing the capital letters from the Code Numbers in front of the lower case letters representing the Code Statements.

STATEMENTS	CODE SECTION
____ a. Motor terminals shall be marked	A. 430-10
____ b. Motor circuit conductors shall have current carrying capacity of 125 percent of full load current	B. 430-81 (c)
	C. 430-103
____ c. Motor controller and disconnects shall not be used as junction boxes for feed through conductors	D. 430-56
	E. 430-22
____ d. Circuit overcurrent devices must open each ungrounded conductor	F. 430-81 (b)
	G. 430-9
____ e. Branch-circuit overcurrent device is a suitable controller for a stationary motor rated at 1/8 horsepower or less	H. 240-20 (b)
____ f. The disconnecting means shall disconnect the motor and the controller from all ungrounded supply conductors	
____ g. Plug and receptacle is a suitable controller for a portable motor rated at 1/3 horsepower or less	

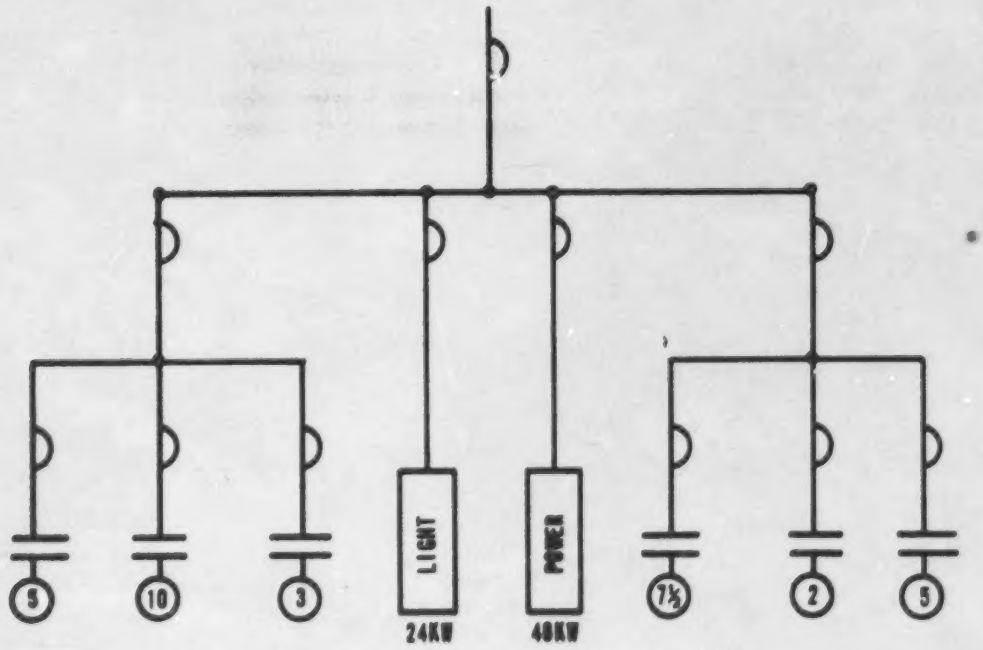
NAME _____ LESSON B-21

DATE _____ WORKSHEET

MOTOR CIRCUIT CALCULATIONS

PROBLEM: Using the National Electrical Code as reference, find the following for the electrical system below rated 120/208 volts, three phase, four wire:

a. Minimum feeder size
b. Maximum feeder overcurrent protection
c. Minimum branch circuit conductors
d. Maximum branch circuit overcurrent protection
e. Maximum motor-running overcurrent protection



NOTE: All motors 3 ϕ with 40° C. rise.
Use code letter "F" for 5 HP motors.
Use code letter "A" on the other motors.
Use 75° centigrade wire temperature (copper).

NAME _____ LESSON B-22

DATE _____ WORKSHEET

LIGHTING FIXTURES

1. Give three examples of "damp locations" which would require special construction:

   a. _____

   b. _____

   c. _____

2. Give three examples of "wet locations" which would require special consideration:

   a. _____

   b. _____

   c. _____

3. How shall the fixtures installed in a clothes closet be located?

   a. _____

   b. _____

4. What section of Article 410 lists the restrictions on closet fixture locations? _____

5. When is "feed-thru" wiring permitted in an outlet box which is an integral part of an incandescent fixture? _____

   _____

6. List the three requirements for a cord-connected electric discharge lighting fixture.

   a. _____

   b. _____

   c. _____

7. A fixture which weighs more than _____ pounds or exceeds _____ inches in any dimension shall not be supported by the screw-shell of a lampholder.

8. A fixture which weighs more than _____ pounds shall be supported independently of the outlet box.

9. What three factors determine the type of wire used in a fixture?

   a. _____

   b. _____

   c. _____ _____ _____

   _____

10. On a screw-shell lampholder where do the wires connect?

   a. Phase conductor connects to the _____ screw.

   b. Identified conductor connects to the _____ screw.

   c. The _____ conductor must connect to the screw-shell terminal screw.

11. Branch circuit conductors within 3 inches of a ballast shall be recognized for use at temperatures not lower than ____ °C.

12. Four of the most used conductor types for fixture channel wiring are:

   a. _____ c. _____

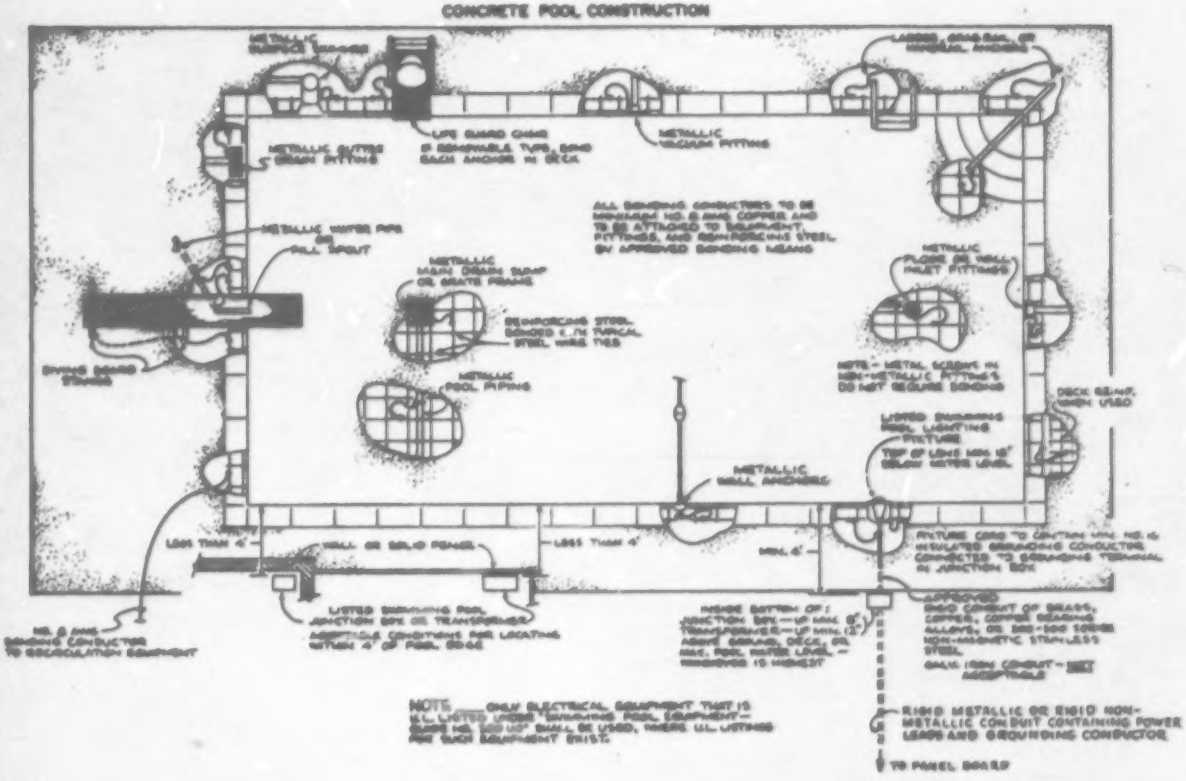
   b. _____ d. _____

13. All wiring shall be free from short _____ and _____ ard shall be _____ for these defects prior to being connected to the _____.

14. N. E. Code Section 410-67 (c) requires "a suitable metal raceway" for recessed fixtures. Is "flex" metal conduit approved? Yes/No ____. Give the N. E. Code Section to prove your answer. _____

15. Section _____ of the N. E. Code covers the grounding of fixtures and lighting equipment.

SWIMMING POOL ELECTRICAL BONDING & GROUNDING


CONCRETE POOL CONSTRUCTION
METALLIC SWITCH & DRAIN FITTING
LIFE GUARD CHAIR
METALLIC LADDER FITTING
METALLIC WATER PIPE OR FILL SPOUT
METALLIC MAIN DRAIN SUMP OR GRATE FRAME
REINFORCING STEEL
METALLIC POOL PIPING
METALLIC WALL ANCHORS
METALLIC FLOOR OR WALL INLET FITTINGS
DECK SLOPE
LESS THAN 4'
WALL OR SOLID FENCE
MIN. 4'
LISTED SWIMMING POOL JUNCTION BOX OR TRANSFORMER
TO CIRCULATION EQUIPMENT
NOTE: ONLY ELECTRICAL EQUIPMENT THAT IS
RIGID METALLIC OR RIGID NON-METALLIC CONDUIT CONTAINING POWER LEADS AND GROUNDING CONDUCTOR
TO PANEL BOARD

"ALL ELECTRICAL EQUIPMENT USED WITH SWIMMING AND WADING POOLS SHALL BE SUPPLIED BY CIRCUITS PROTECTED BY GROUND-FAULT CIRCUIT INTERRUPTERS."

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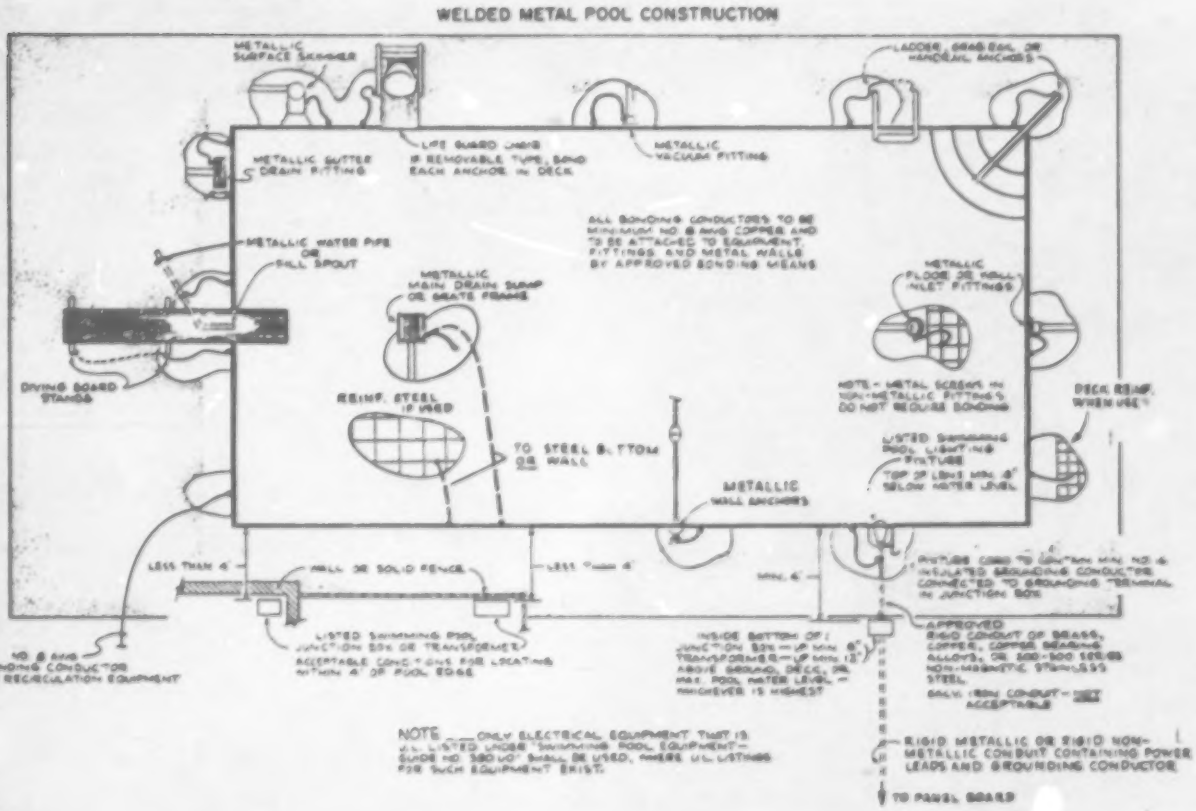
SWIMMING POOL ELECTRICAL BONDING & GROUNDING


WELDED METAL POOL CONSTRUCTION
METALLIC SURFACE SKIMMER
LADDER, GRAB RAIL OR HANDRAIL ANCHORS
LIFE GUARD ANCHOR IF REMOVABLE TYPE, BOND EACH ANCHOR IN DECK
METALLIC VACUUM FITTING
METALLIC GUTTER OR DRAIN FITTING
ALL BONDING CONDUCTORS TO BE MINIMUM NO 8 AWG COPPER AND TO BE ATTACHED TO EQUIPMENT, FITTINGS AND METAL WALLS BY APPROVED BONDING MEANS
METALLIC WATER PIPE OR FILL SPOUT
METALLIC MAIN DRAIN SUMP OR GRATE FRAME
METALLIC FLOOR OR WALL INLET FITTINGS
DIVING BOARD STANDS
REINF. STEEL IF USED
TO STEEL BOTTOM OR WALL
NOTE - METAL SCREWS IN NON-METALLIC FITTINGS DO NOT REQUIRE BONDING
DECK REINF. WHEN USED
LISTED SWIMMING POOL LIGHTING FIXTURE
TOP OF LENS MIN. 6" BELOW WATER LEVEL
METALLIC WALL ANCHORS
LESS THAN 4'
WALL OR SOLID FENCE
LESS THAN 4'
MIN. 4'
FIXTURE CORD TO CONTAIN MIN. NO 6 INSULATED BONDING CONDUCTOR CONNECTED TO GROUNDING TERMINAL IN JUNCTION BOX
NO 8 AWG BONDING CONDUCTOR TO RECIRCULATION EQUIPMENT
LISTED SWIMMING POOL JUNCTION BOX OR TRANSFORMER ACCEPTABLE CONDITIONS FOR LOCATING WITHIN 4' OF POOL EDGE
INSIDE BOTTOM OF JUNCTION BOX OR MIN 6" TRANSFORMER OR MIN 12" ABOVE GROUND, DECK, OR MAX. POOL WATER LEVEL - WHICHEVER IS HIGHEST
APPROVED RIGID CONDUIT OF BRASS, COPPER, COPPER BEARING ALLOYS, OR 300-300 SERIES NON-MAGNETIC STAINLESS STEEL
GALV. IRON CONDUIT - NOT ACCEPTABLE
NOTE - ONLY ELECTRICAL EQUIPMENT THAT IS U.L. LISTED UNDER "SWIMMING POOL EQUIPMENT" GUIDE NO. 380 U.L. SHALL BE USED, WHERE U.L. LISTINGS FOR SUCH EQUIPMENT EXIST.
RIGID METALLIC OR RIGID NON-METALLIC CONDUIT CONTAINING POWER LEADS AND GROUNDING CONDUCTOR
TO PANEL BOARD

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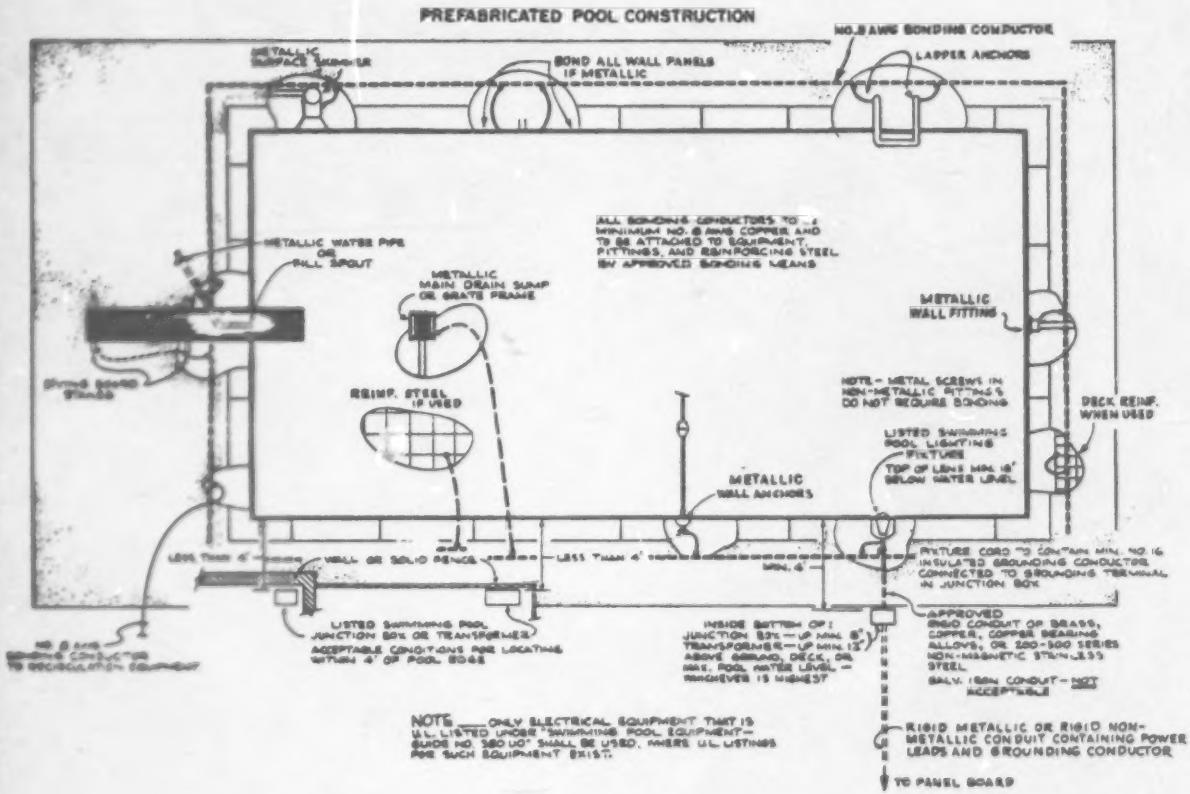
SWIMMING POOL ELECTRICAL BONDING & GROUNDING


PREFABRICATED POOL CONSTRUCTION
NO. 8 AWG BONDING CONDUCTOR
LADDER ANCHORS
BOND ALL WALL PANELS IF METALLIC
ALL BONDING CONDUCTORS TO BE A MINIMUM NO. 8 AWG COPPER AND TO BE ATTACHED TO EQUIPMENT, FITTINGS, AND REINFORCING STEEL BY APPROVED BONDING MEANS
METALLIC WATER PIPE OR FILL SPOUT
METALLIC MAIN DRAIN SUMP OR GRATE FRAME
REINF. STEEL IF USED
METALLIC WALL FITTING
NOTE - METAL SCREWS IN NON-METALLIC FITTINGS DO NOT REQUIRE BONDING
DECK REINF. WHEN USED
LISTED SWIMMING POOL LIGHTING FIXTURE
TOP OF LENS MIN. 18" BELOW WATER LEVEL
METALLIC WALL ANCHORS
WALL OR SOLID FENCE
LESS THAN 4'
MIN. 4'
FIXTURE CORD TO CONTAIN MIN. NO 16 INSULATED GROUNDING CONDUCTOR, CONNECTED TO GROUNDING TERMINAL IN JUNCTION BOX
LISTED SWIMMING POOL JUNCTION BOX OR TRANSFORMER
ACCEPTABLE CONDITIONS FOR LOCATING WITHIN 4' OF POOL EDGE
INSIDE BOTTOM OF JUNCTION BOX — UP MIN. 8" TRANSFORMER — UP MIN. 12" ABOVE GRADE, DECK, OR MAX. POOL WATER LEVEL — WHICHEVER IS HIGHEST
APPROVED RIGID CONDUIT OF BRASS, COPPER, COPPER BEARING ALLOYS, OR 300-300 SERIES NON-MAGNETIC STAINLESS STEEL
GALV. IRON CONDUIT - NOT ACCEPTABLE
NOTE — ONLY ELECTRICAL EQUIPMENT THAT IS U.L. LISTED UNDER "SWIMMING POOL EQUIPMENT" GUIDE NO. 360 U07 SHALL BE USED, WHERE U.L. LISTINGS FOR SUCH EQUIPMENT EXIST.
RIGID METALLIC OR RIGID NON-METALLIC CONDUIT CONTAINING POWER LEADS AND GROUNDING CONDUCTOR
TO PANEL BOARD

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NAME _____ LESSON No. B-23

DATE _____ WORKSHEET

SWIMMING and WADING POOLS, and IRRIGATION MACHINES

1. All _____ shall be approved for swimming pool installation.

2. Maximum voltage permitted for lighting fixtures is _____ volts.

3. All non-current-carrying metal parts of a lighting fixture shall be _____.

4. Service drop conductors shall not be installed above swimming pools or within _____ feet of inside walls of pool, _____ structure, observation _____, towers or _____.

5. Metal wiring enclosures shall be _____.

6. All pool equipment shall be _____ to a common pool ground.

7. Metallic raceways shall not be depended upon for _____.

8. An _____ No. _____ minimum size conductor shall be installed from deck box to distribution panel ground.

9. Transformers used to supply fixtures shall meet the following requirements:

   a. _____

   b. _____

   _____

10. How many grounding terminals are required in a junction box, transformer enclosure, or ground-fault circuit-interrupter? _____
    _____

11. Non-metallic conduit used to feed wet-niche fixtures requires an insulated No. ____ AWG solid _____ grounding conductor.

12. Are all components of a pool water heater required to be grounded? _____. Give the N. E. Code section to justify your answer.
    _____

13. What seven specific items of equipment in a swimming pool are required to be grounded?

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

_____

g. _____

_____

14. The filter pump of a storable pool is required to have double insulation and be effectively grounded. What other protective device is also required? _____

15. Ground-fault circuit interrupter are not required on existing lights fixture and lighting outlets located less than five feet from pool walls. True/False Give Code section. _____

16. Are special provisions made for lightening protection if an irrigation machine has a stationary point? _____ Give Code section for answer. _____

17. What purposes does collector rings serve on irrigation machine?

_____

_____

_____

NAME _____ LESSON No. B-24

DATE _____ WORKSHEET

CRANES, HOISTS, ELEVATORS, DUMBWAITERS, AND ESCALATORS

1. The five major items of equipment for crane power are:

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

2. What is the main difference in the various types of lifting and moving equipment covered in this assignment? _____

   _____

   _____

   _____

   _____

3. The maximum voltage permitted on A.C. system for control and signal circuits is _____ volts except where the maximum current is _____ _____.

4. The maximum voltage permitted for machine motors is _____ volts.

5. Travel cables shall be Type ____, _____, or _____.

6. Type _____ conductor is suitable for installation in raceways on an elevator.

7. The minimum gauge traveling conductor permitted for lighting circuit is No. _____ AWG in parallel.

8. In general, conductors located in hoistway shall be installed in _____ raceways.

9. Raceway shall terminate a minimum of _____ inches above the floor.

10. Conduits installed in hoistway shall be securely fastened to the _____ _____ or _____ construction.

11. Conductors of different systems may be installed in the same conduit provided all the conductors are insulated for the _____ _____.

12. Main feeder supply power to the elevator shall be installed _____ the hoistway.

13. No _____ conduits or wires shall be installed in the hoistway.

14. A _____ means shall be provided at the elevator machine for disconnecting all circuit conductors to the elevator motor.

15. Wiring and equipment located under the car platform of a garage elevator shall be considered in a _____ location.

16. Elevator equipment shall be installed in an area secured against _____ access.

17. A minimum working space of _____ inches shall be provided in the rear of an elevator control panel.

18. Electric elevator machines shall be _____.

EMERGENCY LIGHTING
ADVANCE APPLICATIONS MANUAL

Over the years, the need for Emergency Lighting has been recognized. Codes have been written and people generally have become more concerned about matters of public safety.
It is our attempt in this manual to help you do a good job of planning an Emergency Lighting system for most any type of occupancy requiring it.
The LIFE SAFETY CODE is the granddaddy of all codes dealing with Emergency Lighting. We have summarized and arranged its material in an easy-to-read manner so that this would be handy for use as a Code Reference Guide.
In general, we think of Emergency Lighting as being required to accomplish these two vital objectives during any power failure situation:

- orderly, panic-free exit
- security and comfort of remaining occupants

CODES

NATIONAL CODES

The LIFE SAFETY CODE, published by the National Fire Prevention Association, is the basic national standard. Its purpose is to specify measures which will provide a certain degree of public safety.

LOCAL CODES

State and local codes are generally based on the Life Safety Code, however, the codes do vary. Therefore, you should check with the local authorities in the area in which the building is located. Enforcement is usually by the state or local Fire Marshal, however, enforcement also varies – some local codes apply only when public funds are involved . . . . . others apply for all public buildings.

CODE ILLUMINATION REQUIREMENTS

The Life Safety Code states that the floors of the means of egress ("a continuous and unobstructed way of Exit Travel from any point in a building or structure to a public way") shall be illuminated at all points including angles and intersections of corridors and passageways, stairways, landings of stairs, and exit doors to not less than one footcandle measured at the floor. The Emergency Lighting facilities shall be arranged to maintain the one footcandle for a period of at least one-half hour and at least one hour in hospitals and institutions.

CODE SYSTEM REQUIREMENTS

The system must operate automatically, not requiring manual operation. If the emergency system uses batteries, the batteries must be charged fully when the system is not on emergency operation.

SITUATIONS AND CODE "TYPE" CLASSIFICATIONS

The Life Safety Code lists and describes three classifications of situations in which Emergency Lighting must function:

TYPE I

. . . . . in the event of any public utility failures
. . . . . in the event of any single manual act - such as - accidently opening a switch
. . . . . in the event of any fault in the building's power distribution system

In other words, any INSIDE or OUTSIDE failures.

TYPE II

. . . . . in the event of any fault in the building's power distribution system

In other words, any INSIDE failure.

TYPE III

. . . . . in the event of any public utility failures

In other words, any OUTSIDE failure.

TYPES OF OCCUPANCIES

The Life Safety Code lists, describes, and recommends by "Type" classification Emergency Lighting requirements for various types of occupancies.

Places of Assembly

All buildings or portions of buildings used for gathering together of 100 or more persons for such purposes as deliberation, worship, entertainment, amusement, drinking, dining, or awaiting transportation.

Requirements:

Class	No. of Occupants	"Type" Classification
A	Over 1,000	I
B	300 - 1,000	I, II, or III
C	100 - 300	- - - -

Educational

All buildings used for gathering of groups of 6 or more persons for purposes of instruction such as schools, universities, colleges, and academies.

Requirements:

Flexible plan and open plan building and buildings designed for night occupancy and portions of building having interior and windowless rooms, areas, and corridors – Type I

Institutional

All buildings used for purposes such as medical or other treatment or care of persons suffering from physical or mental illness, disease, or infirmity; for the care of infants, convalescents, or aged persons; and for penal or corrective purposes.

Requirements:

Type I

Mercantile

Stores, markets and other rooms, buildings, or structures for the display and sale of merchandise.

Requirements:

Class	Space	"Type" Classification
A	30,000 sq. ft. or 3 floors	I or II
B	Over 3,000 sq. ft. but less than 30,000 sq. ft. or with any selling floors above or below street floor level	I, II, or III
C	3,000 sq. ft. or less	- - -

Office Buildings

Those used for the transaction of business (other than covered under Mercantile), for the keeping of accounts and records and simular purposes.

Requirements:

Any office building subject to occupancy by 1,000 or more persons – Types I, II, or III

Industrial

Factories making products of all kinds and properties used for operations such as processing, assembling, mixing, packaging, finishing or decorating, repairing and similar operations.

Requirements:

Type I, II, or III

Hotels

Buildings or groups of buildings under the same management in which there are more than 15 sleeping accommodations for hire, primarily used by transients who are lodged with or without meals.

Requirements:

Over 500 rooms	Type I
25 to 500 rooms	Type I or II

Dormitories

Buildings where group sleeping accommodations are provided for persons not members of the same family group in one room or in a series of closely associated rooms under joint occupancy and single management with or without meals.

Requirements:

Subject to 100 or more people – Type I or II

Apartment Buildings

Buildings containing 3 or more living units with independent cooking and bathroom facilities.

Requirements:

More than 25 living units – Type I or II

Underground Structures and Windowless Buildings

Requirements:

Subject to 100 or more people – Type I, II, or III

METHODS OF PROVIDING EMERGENCY LIGHTING

Separate Circuit – Operate certain lighting fixtures from circuits that receive their power direct from the utility line bypassing the main switch gear.

Considerations – Offers no protection against an outside power failure and the constant 120/277V power may be hazardous to fire fighters.

Engine Generator – Operate certain lighting fixtures from circuits that can receive their power from an engine generator, which will "kick in" in an emergency.

Considerations – The batteries used to start it require maintenance. Remote sensing must be provided to make sure that a partial inside failure is detected. Start-up time is 10-30 seconds and the constant 120/277V may be hazardous to fire fighters.

METHODS OF PROVIDING EMERGENCY LIGHTING (continued)

Central Battery – Operate certain lighting fixtures from circuits than can receive their power from a group of central batteries which will take over in an emergency.

Considerations – The batteries require maintenance . . . . they must be kept filled and clean. Remote sensing must be provided to make sure that a partial inside failure is detected.

Unit Devices – Properly locate throughout the building a number of individual units containing their own charger, battery, switch and lamps. The Unit Device has received wide general use because it will take care of all three kinds of power failure . . . . . Outside Failure, Total Inside Failure, and Partial Inside Failure.

Considerations – Wet cell batteries require lots of maintenance. They must be kept filled and clean. Sealed beam incandescent fixtures (traditionally used for emergency lighting) produce harsh glare and shadow.

LAYOUT PLANNING

The required number of emergency fixtures will be dependent upon ceiling height, room size, and reflectances of ceiling, walls, and floor. However, some general guidelines can be followed which, in most cases will provide one footcandle average illumination.

Corridors and All Paths of Egress

are the prime area of concern in all codes – for all types of buildings.

Spacing	Maximum Spacing Feet Between Emergency Fixtures
Recessed Fixtures	35
Surface - enclosed, mounted crosswise to corridor	40
Surface - enclosed, mounted lengthwise with corridor	30
Surface - open, mounted crosswise to corridor	50
Surface - open, mounted lengthwise with corridor	40

and - a fixture should be placed:

. . . . at each intersection of the corridor.
. . . . at each exit location.

Stairwells

are an integral part of any path of egress. Fixtures should be located:

. . . . at every landing with an exit door
. . . . at alternate landing with no exit door mounted either on the ceiling at the edge of the landing or on the wall

Restrooms

are most often overlooked but should be considered in that the code says, "Exit travel from any point in a building."

. . . . Mount a fixture in the center of the room.

Other Uses

Security Lighting – Mount a fixture over every area of vital concern, such as:

. . . . Over every Teller in a bank.
. . . . Over every register in a department store.
. . . . Over areas of very valuable, very portable merchandise on display.
. . . . Over equipment in hospital operating room.
. . . . Over specific pieces of very dangerous machinery in a shop which may keep running minutes after power fails and/or should be safely turned off before leaving.
. . . . Over food preparation areas to allow gas fired equipment to be turned off.
. . . . Over service areas, such as panel boards, heating-air conditioning controls, switches, etc.

Anti-Panic Lighting

Typically, emergency lighting has not been provided in large open areas such as general offices, factories, etc. We recommend the installation of emergency units as Anti-Panic lighting to enable occupants to reach corridors and stairwells.

Coverage	Sq. Ft. Coverage by Emergency Fixtures
Enclosed Fixtures -surface, recessed	1,000
Open Fixtures	1,200

NAME _____ LESSON B-25

DATE _____ WORKSHEET

EMERGENCY SYSTEMS

1. Who sets the requirements for an emergency system installed within a building, plant, church, hospital, or school? _____

_____

_____

2. What five types of electrical services to a building would be connected to an emergency system?

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

3. Why are emergency systems tested on a scheduled basis? _____

_____

4. How much capacity and rating should an emergency system have?

_____

_____

5. What types of emergency systems are covered in Article 700 - Emergency Systems? Name four of them.

   a. _____

   b. _____

   c. _____

   d. _____

6. What device is used to switch the emergency system on? _____

_____

7. Is "feed-thru" wiring premitted in an emergency fixture installed in a continuous row? Yes/No _____. Give the N. E. Code Section on which your answer is based. _____

8. Which type or types of switches are allowed on an emergency circuit to control lighting? [Check the correct answer(s).]

   _____ a. Single-throw switches

   _____ b. Switches in series

   _____ c. Three-way switches

   _____ d. Four-way switches

9. Would a regular automobile battery be approved for emergency system power? Yes/No _____. Give the Code paragraph which covers your answer. _____

10. What prohibits a dry-cell battery from being approved for emergency system power?

    _____

    _____

NAME _____ LESSON B-26

DATE _____ WORKSHEET

MOBILE HOMES, RECREATIONAL VEHICLES, AND PARKS

1. Service to a mobile home is always _____ volts, _____ phase, _____ wire, _____ Hertz.

2. The service conductor to a mobile home can be: (Check the correct methods.)

   _____ a. Thru an overhead conduit mast

   _____ b. One or more approved cord assemblies

   _____ c. An approved underground feeder

   _____ d. Open wiring on insulators

   _____ e. Permanent conduit connection

3. A branch circuit panelboard with its main disconnecting means must be located within the mobile home. Can this equipment be classified as service entrance equipment? Yes/No _____. Reference _____

4. Does the "power take-off" outside the mobile home which feeds one of the service wiring methods in question # 2 to the mobile home have the designation of being the service equipment? Yes/No _____. Reference _____

5. Cord assemblies used for mobile home service power supply are rated ___ or ____ amperes, _____ volts, ____ wire, at least _____ feet long but not to exceed _____ feet overall.

6. The identified conductor (white wire or neutral) and the equipment grounding conductor (green wire) are connected together at the service entrance equipment enclosure and to the grounding electrode.

   In a multi-service mobile home:

   a. Each service has a main overcurrent protective device. Yes/No _____. Reference _____

   b. Each service neutral is isolated from the other neutrals in the other panels. Yes/No _____

   c. Each service neutral is insulated from the equipment grounding conductor. Yes/No _____

   d. Each equipment grounding bus bar for each panel is insulated from each other. Yes/No _____. Reference _____

7. What is the maximum number of power supply cords that may be used to serve a mobile home? _____

8. The minimum size feeder ampacity for a single mobile home lot is _____ amperes and is based on a load of _____ watts per mobile home lot. (Demand factors not included.)

9. The cord and connection assembly for a mobile home is called a _____ _____ and for a recreational vehicle it is called a _____.

10. The minimum rated demand for a recreational vehicle is _____ watts. This would require a minimum of _____ 20 ampere 120 volt circuit(s).

11. Explain how the Identified Conductor (Neutral) and the Equipment Grounding Conductor are terminated in a recreational vehicle.

_____

_____

_____

SAMPLE HOUSE PLAN

(BLUEPRINT READING)

The attached house plan has the following items of electrical equipment.

1.	Range - 230 V 1Ø	12 kw
2.	Disposer - 120 V	7.2 amps
3.	Dish Washer - 120 V	1350 W (13 amps)
4.	Clothes Washer - 120 V	9.8 amps
5.	Clothes Dryer - 230 V 1Ø	5.0 kw
6.	Electric Water Heater 230 V 1Ø	4.5 kw

The electric heating requirements; use one of the following systems:

ROOM NAME	SCHEME # 1 BASEBOARD	SCHEME # 2 CEILING CABLE	SCHEME # 3 CENTRAL ELECTRIC FURNACE
Living Room & Hall	3000 W	3000 W	230V 1 Ø
Dining & Kitchen	2000 W	2000 W	10 KW
Bedroom # 1	1250 W	1400 W	Duct Bank
Bedroom # 2	1250 W	1400 W	+ 1/3 HP 120V
Bedroom # 3	1000 W	1000 W	Fan
Bath # 1	500 W	400 W	
Bath # 2 (Half Bath)	500 W	200 W	

NOTES:

1. Optional cooling is by either of the following systems:

	Baseboard or Ceiling	Electric Furnace
Bedroom # 1	6.9 amp @ 230 V window unit	20,000 BTU Condenser @14.6 amps
Dining & Kitchen	9.8 amp @ 230 V window unit	230V + Fan at Furnace

NOTES (Continued):

2. It is interesting to note that the heating loads are different for the various systems. This is due to standard sizes of items and not from one system being more efficient or less expensive to operate than another.

   Baseboard Heaters - 8500 watts

   Ceiling Cables - 9400 watts

   Electric Furnace - 10000 watts

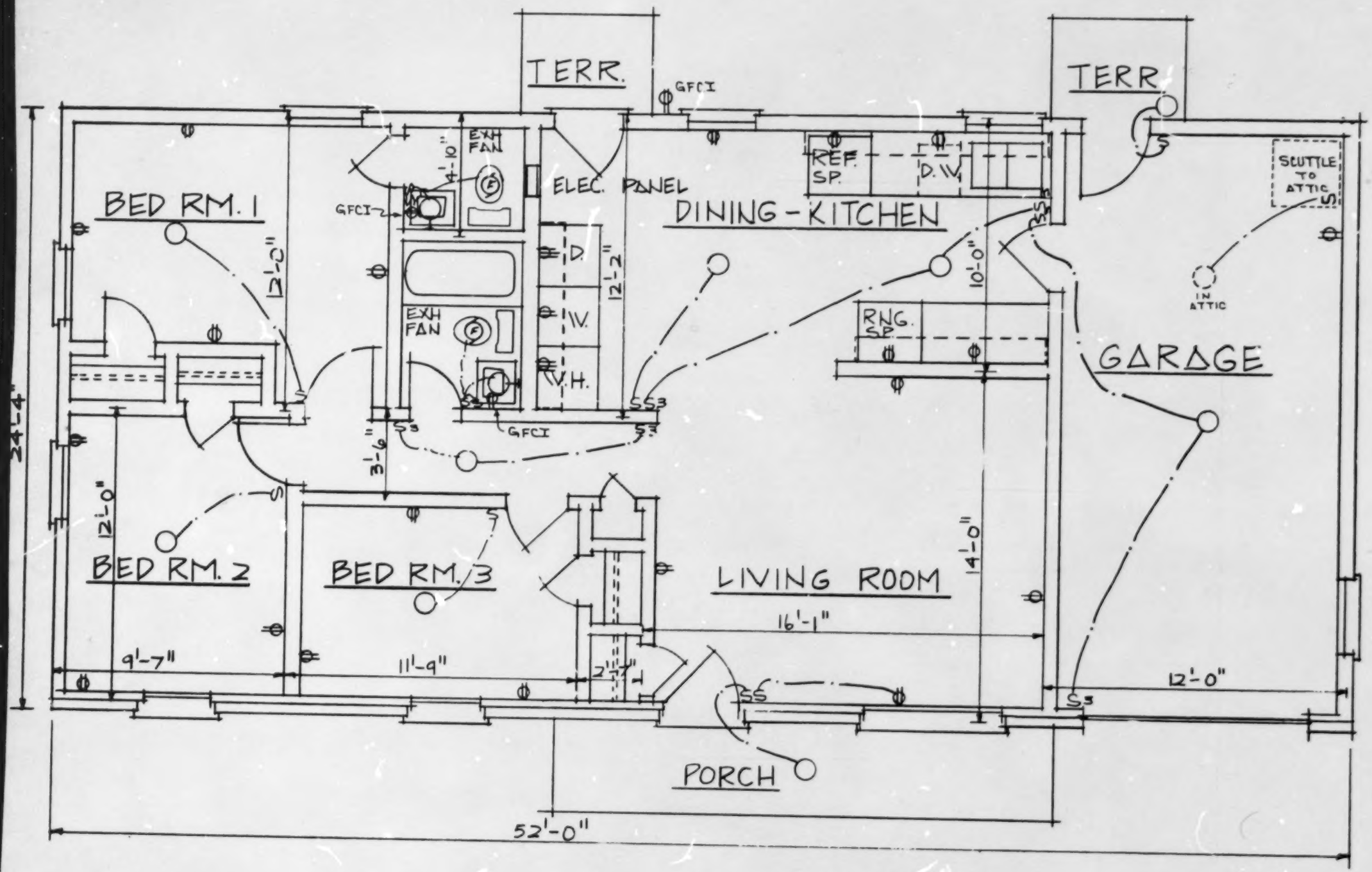
3. By the same reasons, the cooling systems differ:

   Central unit in furnace - 20,000 BTU

   Dining/Kitchen window unit - 15,000 BTU

   Bedroom # 1 window unit - 8,000 BTU

4. Both heating and cooling requirements assume construction typical for a home which qualifies for the "all-electric" rate from the serving utility, and a design temperature range for heating of 10° F outside and 70° F inside. Naturally, it would not be as much of a temperature differential for the cooling - 70° F inside to 95° F outside (estimated averages).



FLOOR PLAN

1978

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STUDENT: GARY ROBBINS
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SHEET NO. 1 OF 1

FLOOR PLAN

GUILFORD TECHNICAL INSTITUTE, JAMESTOWN NC

ARCHITECTURAL TECHNOLOGY DEPARTMENT

NAME _____ LESSON B-28

DATE _____ WORKSHEET

OUTLET CIRCUITING

1. From the floor plan in Assignment B-27, calculate the load data and circuit the following on your floor plan:

   (a) Lighting outlets. Load in watts _____

   (b) Receptacle outlets. Load in watts _____

   (c) Small appliance outlets. Load in watts _____

2. List the number and ampacity of the circuits required for:

   (a) Lighting outlets:
   Number required _____.
   Ampacity of circuits _____.

   (b) Receptacle outlets:
   Number required _____.
   Ampacity of circuits _____.

   (c) Small appliance outlets:
   Number required _____.
   Ampacity of circuits _____.

3. From the information sheet in assignment B-27, complete the following schedule:

ITEM	VOLTAGE	AMPS	WATTS	WIRE SIZE	CIRCUIT PROTECTION
Range	230	_____	12000*	_____	_____
Disposer	120	7.2	_____	_____	_____
Dishwasher	120	13.0	1350	_____	_____
Clothes Washer	120	9.8	_____	_____	_____
Clothes Dryer	230	_____	5000	_____	_____
Water Heater	230	_____	4500	_____	_____

* Use Demand Table 220-5

4. From the Information Sheet in Assignment B-27, select one of the three schemes of heating. Give your answer to the following:

   (a) Scheme chosen _____

   (b) Number of circuits required _____

   (c) Ampere rating of each circuit _____

   (d) Overcurrent protective devices needed for these circuits and their ampere rating _____

5. From the Information Sheet in Assignment B-27, select one of the two methods of cooling which would match the heating system you chose above. Give your answer to the following:

   (a) Scheme chosen _____

   (b) Number of circuits required _____

   (c) Ampere rating of each circuit _____

   (d) Overcurrent protective devices needed for these circuits and their ampere rating _____